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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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LESLIE GORDON,
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The Public Trustee does not bind himself to accept any Tender, and reserves to himself all rights in connection therewith.

Forms of Tender can be obtained from the PUBLIC TRUSTEE.

Dated this 9th day of February, 1917. 5943

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G 557

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Engineer, shortly visiting Russian industrial centres on business trip, DESIRES to ENTER into NEGOTIATIONS with responsible firms requiring reports on possibility of future business in that country.—Address, in first instance, G 500, Offices of ENGINEERING.

SURFACE SUBSIDENCE DUE TO MINING OPERATIONS.

EXTENSIVE excavation, such as is necessary for the recovery of coal or other mineral, cannot be carried on without diminishing the strength of the surface support, and the more extensive the mine and the wider the underground workings, the greater the hazard that cracks and fissures will manifest themselves in the surface strata above the excavations, to be followed in extreme cases by the fall of the roof. When mining is prosecuted in undeveloped countries—and it is usually in sparsely populated areas that the greatest mining activity is displayed, or at least originated—the effects of surface displacement may be little regarded, but as population increases and property on the surface becomes more valuable through the outlay of capital, the necessity of preserving a rigid undisturbed surface becomes of importance, and the neglect of proper precautions a matter of complaint. The increase of land occupation, the greater area required for town expansion, the construction of railways and canals, have all brought the effects of subsidence pressingly forward, and recognising the altered conditions due to denser settlement, the Engineering Faculty of the University of Illinois has rendered good service in collecting the information spread through an extensive literature bearing on this subject, and presenting the salient points in a form that is both popular and accurate.*

One of the results of the co-operation of the authors of this monograph is to show that more precise information is needed concerning those processes at work underground that give rise to a change of level and cause subsidence. Carefully designed observations are necessary to success, and proposals are made for carrying out methodical inquiries throughout the State of Illinois. The explanations that are given by engineers and geologists are usually inferences drawn after the event, when the removal of the supporting strata has been more or less completely effected, destroying the evidence that would explain the cause and order of the bending movements that produce the instability in the overlying beds. The gradually altering conditions in the mine as excavation proceeds cannot be reconstructed with certainty, many steps in the process have to be supplied from conjecture, and sometimes, it is to be feared from the character of expert evidence, are suggested by interested motives. In any case a series of carefully planned observations carried out over a considerable extent of country in which deep-seated mining is being actively prosecuted cannot but produce a mass of information that will be highly informing, free from bias, and of great value in settling opposing views.

The question of permissible excavation, however, must be considered in another and broader aspect, and one in which public claims may be in conflict with individual rights. Minerals, whatever their nature, are not inexhaustible, and it is eminently desirable for the public good that their recovery in any district should be as complete as possible. Such recovery may be incompatible with the interests of the surface owner. For example, where pillars are left, as in many coalfields, to support the upper strata and ensure the integrity of the surface, the mineral embedded in these pillars is practically lost to the community, and yet the agricultural value of the land, or even of the buildings erected on it, may be small in comparison with that of the unmined minerals. Is the owner of the land, then, justified in demanding that the mining shall be conducted in such a way that the surface remains undisturbed? Can public utility, in spite of vested interests, claim that a valuable and gradually disappearing mineral shall be made available for general use and not left in the ground as worthless rock, only to support the surface? Is the permanent loss of the mineral to be weighed against the temporary injury of the surface features? These questions raise problems in law and equity to which a solution has to be found. There are other points of economic importance, such as the appropriate massiveness of the pillars at different depths, and their distance apart, with which, again, are connected other factors that have been settled more or less haphazard. The geological, as well as the physical problems, cannot be neglected, and these, like other aspects, receive a very satisfactory examination at the hands of the authors, who regard a comprehensive survey of the complicated subject as a useful preliminary measure to the collection of further information by means of a detailed and co-operative investigation of subsidence conditions in Illinois.

The evidence of surface subsidence assumes many forms, and for examples we need not look beyond our own country, where, owing to the long pursuit of mining operations in thickly populated areas, the distinctive signs are more pronounced and their history more trustworthy than in the States, where scant attention, till late, had been directed to the main facts, owing to the small pecuniary value set on the soil. Among our oldest mining industries is that of salt, and a well-known and prominent cause of subsidence is prevalent in the districts where salt mining is carried on. In the salt mines of

Fig. 1. TENSION AS A CAUSE OF SURFACE CRACKS

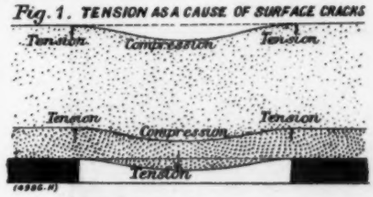
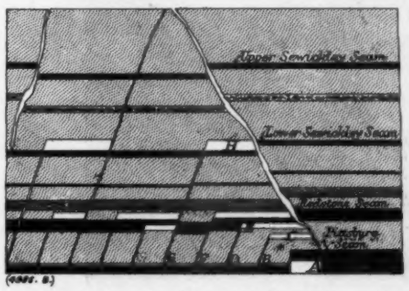


Fig. 2. PROBABLE EFFECT OF REMOVAL OF PILLAR COAL



Cheshire, within a depth of 390 ft. from the surface, there is a total thickness of not less than 200 ft. of salt. The removal of any considerable portion of the salt offers all the conditions favourable for subsidence, more especially as the method now employed, that of pumping, does not permit of the retention of supporting pillars or of replacing the soluble material. In a natural condition the water in or on the salt beds becomes saturated, and then can dissolve no more. Modern pumps rapidly remove this saturated solution, and the fresh water which flows in to take its place dissolves the salt pillars which have supported the roof and overlying strata, with the result that there is a depression towards each pumping centre. The mines in the upper bed of rock salt are being destroyed by water rapidly eroding the salt pillars, relics of more primitive days of mining. The far-reaching effects of the consequent subsidence is proved by the necessity of adopting framework buildings, so that when one of these sinks it can be lifted by screw-jacks and put back into its original place. In such a case there may be no rupture of the surface material, but apparently an accommodation of the exterior to the sag of the underground strata. There will be a bending action producing compression in the centre of the basin, or excavation, and tension round the rim; this tension may become so great that rupture is produced, as indicated in Fig. 1.

Coal mining is, of course, responsible for so much surface subsidence that examples are scarcely necessary. The winning of coal under the Merthyr Tunnel caused a fall of 10 ft. in 1½ miles of tunnel, of so irregular a character that the line had to be cut down to make the grade uniform. In South Staffordshire it has been found difficult to find foundations for reservoirs; one of 43,000,000 gallons content, set in the midst of workable beds of coal, sank 4 ft. more at one end than the other, the great difference in level between the ends being attributed to a fault. Indeed, so numerous are the instances that the question has been raised whether there is any depth at which mining may be carried on with impunity. The question is still *sub judice*, authorities being about equally divided. The effect of subsidence is cumulative in long periods of time, and its detection requires accurate determinations of level over extensive areas, and the repetition of such measures at distant intervals. With the small changes, that vary with or depend upon the character of the superficial strata, are involved the secular alterations in the mean sea-level at the base of a level line. The problem is one of great practical interest, worthy of pursuit by the Illinois Engineering Experiment Station. In this country there is some evidence to show that in the Midland and South Yorkshire coalfields mining at a depth as great as 2,000 ft. has caused some noticeable subsidence. In Wales the sinking of the surface from 10 to 15 ft. has been traced to mining operations on the pillar and stall system at a depth of 1,800 to 2,400 ft. In Derbyshire, where "longwall" is practised, the maximum subsidence was only 1.74 ft., the mining depth being 1,600 ft. The economic importance of such records is shown in the possibility of pursuing subaqueous mining with safety when only a moderate thickness of strata separates the seam from the sea floor. Seams have been worked without accident with only 126 ft. of strata between the bed and the sea where longwall filling has been adopted, but mining on the pillar system is prohibited where there is less than 360 ft. of intervening strata. No grave disaster is reported from overflow into the workings of a subaqueous coalfield in this country, but in Cape Breton Island a colliery was lost by a flood, occasioned by the removal of pillars which were believed to have no less than 942 ft. of solid strata between the coal seam and the ocean bottom. The serious accident in Japan some two years ago emphasises the necessity for caution, and the enforcement of drastic legislation fixing the dimensions of pillars and stalls and insisting on constant watchfulness in advance of the work. Any precaution may prove unavailing, as was shown in Japan, the mine being completely flooded in two hours, the quantity of water being estimated at 392,000 cub. yards. So large an amount of solid matter was washed in, that apparently the opening in the fault which caused the inrush was so effectually sealed that it was proposed to fill up the depression with clay and sand, pump out the water, and reopen the mine.

In the more ordinary course of mining the origin of the fracture and the gradual spread horizontally and vertically which results in subsidence is illustrated in Fig. 2, which shows the effect of a gradual removal of the pillar in a small seam, 250 ft. below the surface. The first break occurs at B, due to drawing the pillar from A to B 40 ft., producing the cavity C; the second fall takes place at D, the fracture line extending to the space E in the Redstone seam. This break occurs after 60 ft. have been traversed, and the break extends to more than 40 ft. above the floor of the Pittsburg seam. The third fall is prolonged to F, and the fourth to G, the line of fracture in the latter case reaching the space H in the Lower Sewickley seam, 85 ft. above the Pittsburg, the total length of pillars drawn up to this stage being 100 ft. It is easy to follow the successive breaks and consequences till the surface is reached, where a possible breach of continuity may be produced. In Illinois fissures 2 ft. wide have been traced to similar operations, but 6 in. are of more common occurrence, of which there are examples in the anthracite district.

Forces have operated differently where ponds and caves have been formed, often to the detriment of agriculture and the injury of building sites. These effects are due to the working of mines at shallow depths with little rock cover, so that the roof without sufficient support falls as one piece. Fig. 3, page 342, shows a pit hole marking the position of a mine from which coal 6 ft. or 7 ft. thick had been extracted at a depth not exceeding 100 ft. The overburden, consisting of about 10 ft. of shale and 90 ft. of

* "Subsidence resulting from Mining," by L. E. Young, Mining Engineer for the Illinois Coal-Mining Investigations, and H. H. Stock, Professor of Mining Engineering, University of Illinois. Published by the University of Illinois and by Chapman and Hall, Ltd., London.

drift, had operated like a beam, and when the underlying strata had proved unequal to the task of upholding the weight, had fallen as one piece. Such instances are frequent in the anthracite districts. It is easily seen that where coal has been removed from shallow depths, though there may be no actual rupture at the surface or fallen roofs, yet the gradual subsidence over a large area may prove very detrimental to agricultural interests. On the flat prairie-land natural drainage is practically absent, and large sheets of water may stand for a long time, reducing the productivity of the soil. In the Mississippi Valley, where the streams are bordered by extensive bottom lands, little, if any, above the high-water mark, it is claimed that surface subsidence will materially increase the area flooded at the time of high water, or make the land too wet for farming purposes. The day is coming, if it has not arrived, when the value of the land for agriculture will be greater than for coal-mining. These altered conditions emphasise the importance of the inquiry set on foot by the University of Illinois.

The surface disturbances caused by excavation will be further conditioned by the character of the geological structure of the displaced material. The strata may vary from a plastic clay and incoherent sand to solid granite, but whatever be the material, these strata, when subjected to stresses, will behave differently under different loads. The direction of fracture and of cleavage is equally indeterminate, and herein lies a wide field for experiment, but unfortunately the tests of the laboratory, as at present conducted, afford little real information. The investigator requires data based upon larger volumes of material, greater and more slowly acting forces, and conditions more nearly approximating to those which result from mining operations. To secure stability, or, if that be impossible, to diminish loss and disaster, attention will be centred on three main factors, the physical character and composition of the deposit left in the supporting pillars, the underlying rocks on which these pillars stand, and the overlying measures between the pillars and the surface. The pillar that in its original state was considered equal to supporting an approximately known burden may be considerably weakened after being subjected to the action of explosives, the effect of water or a damp atmosphere. Some coals, for example, are very friable, and the cohesion, as well as the dimensions of the pillar of such coal, suffer from concussion. Soluble material in the pillars will be dissolved by mine water or the moisture of the air. Pyrite and other minerals will become oxidised and suffer deterioration. Air blasts are frequent in some mines, and these are accompanied, or occasioned, by constant displacements of masses of rock from the pillars and stoped-out portions. The violence of the detachment is so great as to suggest that the rock is under some condition of strain that is suddenly relieved, but such relief means a partial shattering of the supports. Other forces than gravity are at work, and for such reasons elaborate strength tests on small samples are of little service, and may prove dangerous if they induce a confidence that is not warranted. Tests, too, can easily mislead, since they indicate the maximum load that can be borne by a unit of the material. In a coal bed layers of varying hardness are encountered, but the selected sample shows no evidence of this variety. Tests, however, grow more trustworthy as they increase in number, by reason of the greater experience brought to bear on the problem. In these improved circumstances it is usual to admit that the squeezing strength of a pillar of anthracite whose width is twice its height is about 3,000 lb. to the square inch, and the crushing strength twice as great. In tall pillars, having a height greater than their width, the squeezing strength apparently remains nearly constant, while the crushing strength continues to diminish, varying inversely as the square root of the thickness of the bed.

If the strength of the pillar does not fill us with an abiding confidence, the overhanging strata and the underlying bed are likely to prove even more treacherous. The former is rarely uniform: not infrequently sandstones and slates overlie mineral veins, and when these are continuous they may be regarded as beams or slabs spanning the mine openings, upholding the superimposed load. From this point of view the transverse strength is of the first importance, for the ability to serve as a supporting beam depends upon the tensile strength, and this is always less than that of compression. The following short table indicates the relation between unit stresses and the absolute values American authorities are inclined to adopt:—

Description of Stone.	Compression.	Shear.	Tension.
	lb. per sq. in.	lb. per sq. in.	lb. per sq. in.
Blue stone flagging ..	1500	—	200
Granite	1020	200	150
Limestone	800	150	125
Sandstone	700	150	75

The underlying rocks will frequently be incapable of supporting a burden that the pillar itself might sustain. When the underbed is of clay, it often happens that the pillar is slowly pushed into the clay, or the clay bed may be softened by water and forced upward by the weight of the pillar, giving rise to a movement known as "creep." Possibly a "creep" formed in this way would not be conveyed to the surface, or would exhibit a nearly inappreciable subsidence. On the other hand, it is possible to meet with a rock that in its native bed would possess a bearing power of 200 tons to the square foot. It would not be safe to trust clay under favourable circumstances with a weight greater than about 6 tons to the square foot; sand would be even less firm, so that the range of stability is fairly great.

The theories put forward by authorities to explain the mechanics of subsidence are as interesting as their disagreement is marked. Local experience has often influenced opinion, and such a bias is fatal to the formation of a theory that shall embrace all the diverse conditions under which mining is prosecuted. The excavation may be long and narrow, through massive or bedded rocks. The width may be increased, as in "pillar and stall" mining, or have even greater lateral extension, as in "longwall" mining. The material upheld may be regarded as a horizontal or inclined beam, as a cantilever, or an arch, or a vertical column, or varieties and combinations of these forms. To reduce order out of such incongruous material is a hopeless task. To demonstrate the observed facts as the consequences of any simple law would seem to pass the wit of man. At a recent geological congress Professor George Knox was able to enunciate only two propositions that have such general acceptance among geologists and engineers that they may be considered sufficiently well established to form the basis for further investigations. These two, that read almost like axioms, are: (1) "That surface subsidence invariably extends over a greater area than that excavated"; (2) "The angle of pull is determined by the ratio between the excavated and subsided areas." It may also be admitted that this ratio is conditioned by a large number of factors, but whether the catalogue of a round dozen enumerated by Professor Knox exhausts the list, or how far some of these may be consequences of a common law, cannot yet be decided. Thirty years ago Mr. A. Fayol took a mischievous delight in contrasting the diverse views that obtained support in his day, and all of these may still have the advocacy of experts. Some held that the upward movement was transmitted to the surface independent of the depth of the workings, while others as stoutly upheld that the surface remained unaffected when the workings exceeded a given depth. Another school asserted that movement became more feeble as it extended surfacewards, in contradiction to the alternate view that subsidence reached the surface without sensible diminution. Whether subsidence took place vertically, or along lines normal to the bed, or at some angles between the two, has divided mining experts

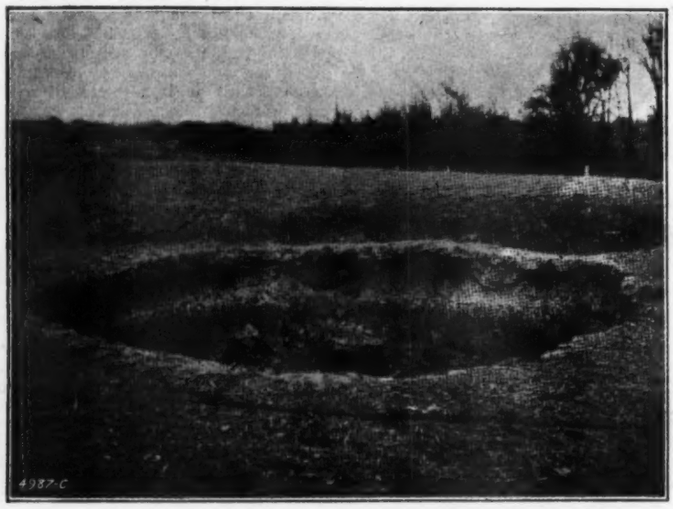


FIG. 3.

Fig. 4. "ZONE OF FALLING" AND ZONE OF TEARING

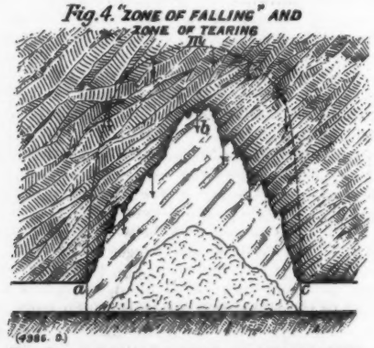
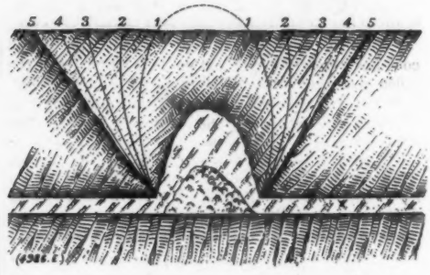


Fig. 5. SUBSIDENCE OUTSIDE UNDERMINED AREA.



since Gonot first enunciated the much-debated "Law of the Normal." Lastly, "packing" or "gobbing" was claimed as an efficient protection of the surface, also as a means of reducing the effect of subsidence, and, finally, that subsidence was greater with stowing than without it. Such irreconcilable statements involving very practical results are not edifying, and some evidence could be produced in support of each. No one would say that subsequent inquiry has removed all doubts, or that controversy has entirely disappeared.

In the midst of such contradictions wisdom would point to the preservation of a discreet silence, leaving all hypotheses severely on one side. But as Fayol's main suggestion of limiting the movement to a dome or arch has found many advocates, as it explains observed facts, illustrates general principles, and can claim some support from experiment, some of the more developed variations deserve a brief reference. We shall follow M. Rziha, of Vienna, who has pursued this dome theory with some thoroughness. In considering what would happen to overhanging rock when the action of gravity exceeded that of cohesion, he concluded that the rock would become loosened, and afterwards fall, creating a "falling" space, surrounded more or less concentrially by a "tearing" space, the whole tending to assume a paraboloid form. In time, conditioned by the structure of the rock, a domed space represented by *a b c*, Fig. 4, working laterally and vertically from the centre of disturbance, would be formed. Outside this space is the dome of "tearing" action indicated by the dotted line *a m c*. Evidently *m* may extend above the surface, originating extensive collapse, and in that case the overhanging wall will change its slope, "depending upon the lateral extent and degree of the tearing and the relation between gravity and cohesion." This later stage is suggested in Fig. 5.

Rziha's genesis of the arch theory has had many critics and some support from those who have studied the mechanics of natural rock arches, and from engineers, who, however, disagree among themselves as to the portion of the burden of the overlying beds actually borne by arches. Among others, Mr. B. S. Randolph has employed the method to explain some of the phenomena of crushing that are common in coal seams. In Fig. 6 coal has been removed between A and B, and the fallen material produces an irregularly domed roof, A B C. The dotted line A′ C′ B′ indicates the line of stress impinging on the coal near to A. The stress at this point represents half the weight of the strata overlying the span A B, which may be sufficient to crush the coal about A. When this has been effected the arch is weakened, and the line of stress assumes the position D E B′. Naturally this movement will be no greater than is absolutely necessary to gain a solid footing for the arch, which, again, will be so near the edge of the coal already crushed that it will fall again in a short time, necessitating a further adjustment of the position of the arch. In this way it is suggested that crushing, or squeezing, is brought about. If the solid coal, A F G H, be quickly removed, a fall may result, extending above the seam to the line F J B, which will cause the line of stress to move quickly and reach the coal well back from the point F, where it is sufficiently solid to give the needed support, and "the working will be said to have gotten ahead of the crush," while, in fact, the crushing force has gone ahead of the work. Such a theory explains some of the common experiences in mining, while possible variations in the position of the arching line and of the tensile strength of the strata would account for the action first becoming noticeable at a considerable distance from the pillars.

The behaviour of the strata within a limited arch can be shown by an experiment due to Fayol. He arranged boxes, permitting convenient observation through glass sides, of horizontally arranged artificial strata submitted to stresses of known amounts. The bottom of each box was covered with narrow strips of wood, any of which could be removed, to imitate excavation. Other strips could be placed on these, or a layer of material to represent a geological stratum, carrying other layers of different material and thickness. The arrangement is shown in Fig. 7. The withdrawal of the strips of wood represented the removal of an ore body, and the effect of the missing support could be traced on the artificial strata above. The lowest bed in contact with the wood, shown by the numbers, which give also the order of removal, was of dry sand. This fell as each strip was pulled out. The second bed, of more coherent material, did not sink till after several strips had been taken away, a slight curve in the successive strata becoming apparent, having the greatest deflection towards the centre of excavation. Not till the twelfth had been withdrawn did the movement reach the topmost layer. With continued removal up to the seventeenth, taken in the order shown, the beds became bent, the limit of the deflection being the curves Z13–Z17. The lines marked A show the greatest deflection of the sunken beds after the removal of the strip correspondingly numbered. On the removal of a second row of wooden strips, corresponding to doubling the excavation, some of the lower beds fell in, but at the surface the disturbance was not increased: the maximum deflection, however, ceased to remain vertical.

It will be asked whether laboratory studies or practical experience has been able to establish

Fig. 6. ARCH STRESSES IN MINE ROOF

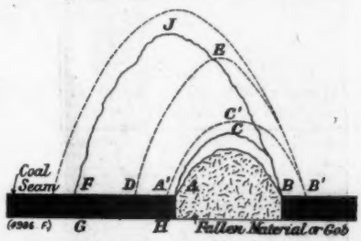
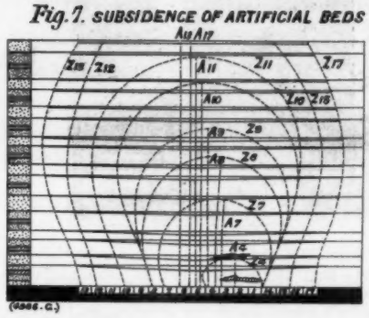


Fig. 7. SUBSIDENCE OF ARTIFICIAL BEDS



securely a definite theory, or to provide precise rules that shall afford protection against the more common dangers due to subsidence, and it must be admitted that this degree of success has hardly been attained. The number of variables is so large, the research is so wide, that so far from settling the main questions that come to the fore, our engineers have barely arranged a programme for inquiry and observation. The preliminary work of the Illinois Engineering Station is to sift evidence, to analyse reports, to separate the fundamental from the accidental, and to indicate the road along which investigation can be usefully prosecuted. The abstract put forward demonstrates not the need for more facts, but for intelligent guidance through the contradictions and intricacies that have accumulated through the observation of non-essentials. The lack of precision and the uncertainty in determining the true principles of scientific guidance are amply demonstrated by the variety of rules that have been formulated for the dimensions of shaft pillars in flat seams. One authority says that for a depth of 300 ft. the pillar should be 66 ft. square. For the same depth another advises 102 ft., while a third, and the most extravagant, proposes "1 ft. in breadth for every foot in depth." At 300 ft. he would have a circular pillar of 150 ft. radius, or a square pillar 284 ft. in the side. Many other rules are given, but it is impossible to detect the scientific principles by which the respective authors have been guided in their decision. We do know, however, that the ability of the pillar to carry the load is not the only, and possibly not the main, factor to be considered. The unknown amount of draw or pull over the pillar is equally an important control, and the relative stability of the underlying bed, with its capacity to sustain the load concentrated upon it, complicates the problem. We must therefore expect a large "margin of safety," but such a term is hardly applicable to the figures quoted. The dimensions of pillars and the width of stalls, where that system is employed, show, in proportion, as large a diversity as shaft pillars, but here experience, which has more opportunities for its exercise, is less likely to go astray. Under generally favourable conditions the American rule is to make "the thickness of room pillars equal to one per cent. of the depth of cover for each foot of thickness of the seam . . . and make the width of the room equal to the depth of cover divided by the width of pillar thus formed."

The process of filling or of providing protection to surface, to hanging walls, mineways, &c., does not present the same difficulties. The space to be filled is definite, and ingenuity has suggested many ways by which this can be accomplished. But the filling is only partial. There are many voids, and neither the supporting strength of the filling nor the amount of subsequent compression is known with accuracy. The problem, however, is simpler, so much cubical content has to be filled as compactly as possible, and whether the materials are best fitted or best applied is generally a financial, rather than a mechanical, problem. If the filling is unsatisfactory, the problem is likely to assume another shape, the legal. The authors, in a final chapter, address themselves to this last stage, but here we have neither the knowledge to criticise nor the training to benefit by their researches. The chapter, however, is as interesting as those dealing with the mechanics of the subject, and is marked by the same capacity to crowd the page with facts, while preserving distinctness and lucidity. The authors' digest is thorough and illuminating, and we note with satisfaction that it marks only the first stage on a long journey. Informed of what is needed, and guided by the labours of others, they propose to make a scientific and detailed survey of the problem that will extend over many years, but under circumstances that promise success.

THE INSTITUTION OF NAVAL ARCHITECTS.

(*Concluded from page* 334.)

In our last two issues we have given reports of the discussions at the recent meeting of the Institution of Naval Architects. Three papers still remain to be dealt with: "Theory of Wave Motion in Water," read on Thursday morning, the 29th ult., by Sir George Greenhill; "On Launching Ships," by Mr. P. A. Hillhouse and Mr. W. H. Riddlesworth; and "Buoyancy and Stability of Submarines," by Professor W. Hovgaard. The two last were read on Thursday afternoon.

Theory of Wave Motion in Water.

This paper was read by the author in abstract, wave motions being illustrated with the aid of small models presented by Mr. W. B. Croft, of Winchester, one apparatus showing analogous wave-motion in the vibration of a chain rotated by a small dynamobile.

In his paper Sir George Greenhill stated that some knowledge of the theory of the wave was exacted of the student of naval architecture, but it was noticeable to the outside critic how the Rankine theory of the trochoidal wave seemed the only treatment studied and expected. The text-book prescribed must have been, he added, "Naval Architecture," 1894, by W. H. White, where Chapter V was devoted to the deep-sea wave, treated as trochoidal in Rankine's manner, with appropriate numerical illustrations taken from observation at sea. The author then proceeded to elaborate his theory; this is based on so many formulæ that it cannot be briefly abstracted.

Sir William E. Smith thought the author's opening remarks might perhaps lead to Sir William H. White's work referred to being misjudged. He (the speaker) had been first a pupil of, then an assistant to Sir William, whom he later succeeded,

and he was acquainted with his views on wave motion. Chapter V in his book was set out in the simplest terms, and gave a large amount of information as to actual results observed at sea, means of measuring waves, the effect of heaving motion, and so on, but that chapter was not destined to instruct professional students as to the structure and general mathematics of trochoidal waves. As a matter of fact the instructions given with reference to the trochoidal wave had never been given by the instructors in naval architecture at Greenwich, but by the professors of mathematics and applied mechanics, and this had been done in a very thorough manner. Sir William White, as Director of Naval Construction, had himself set many papers. Molecular rotation was perfectly known to Sir William. He (the speaker) added that the question of shear, referred to by Sir George Greenhill, was likely to prove a powerful analytic and an interesting method. He also thought that much was due to the Woolwich School of Mathematics, and great assistance had been obtained from the able men of that school.

Sir George Greenhill, in the course of a brief reply, said that the difficulty of making the rotation in the Rankine wave attracted attention at the very outset. Stokes had written on the subject and Rankine had replied. It was a difficulty inherent in the construction of that peculiar state of motion invented by Rankine. The instructor, in putting the theory before his class, had to do so in an elementary manner and to keep out of sight the metaphysical unreality of the motion being such as could not be generated, or if once generated the liquid must have been created in that state from the beginning. Sir William White, he knew, was perfectly familiar with all the criticisms of the theory, but as he was writing a book on naval architecture and not a treatise on wave motion he had not gone into detail; Sir William was aware of all the figures in the theory.

The chairman then called for a cordial vote of thanks to the author and to Mr. Croft, which was heartily responded to.

The thanks of the meeting were then given to the Marquis of Bristol, who was unable to take the chair at the following afternoon meeting.

On Launching.

The next paper was "On Launching," Messrs. P. A. Hillhouse and W. H. Riddlesworth being the authors. The paper gave a schedule for systematising and simplifying the predetermination of launching conditions, and discussed the relative advantages of different arrangements of fore poppet. We commence its publication in this issue.

The discussion was opened by Sir William Smith, who said that launching calculations originated in an accident which occurred on the Thames some thirty to forty years ago in launching the Independencia. This vessel tipped when passing down the ways. The Chief Constructor at the Admiralty was then Sir James Crossland, who thereupon instituted calculations for future guidance in the designing of launching ways. These were first made for the troopship Assistance and were circulated to all the dockyards, where the plan of making launching calculations became standard practice. As experience was gained more and more factors were taken into account. When the Nelson was building at Fairfield, proposals for launching were sent to the Admiralty for approval. Calculations were made accordingly, and the builders advised that to avoid the risk of tipping the ways should be lengthened 50 ft. This, it was stated, was impossible, but 25 ft. were added to the length. The Admiralty accepted the compromise, but warned the builders that the ship would be likely to balance about the end of the ways, which would give rise to severe crushing forces on the ship. The chance was, however, taken. The ship did tip, and broke some frames, but was successfully got off. The question of launching calculations was next taken up by shipbuilders, and especially by Mr. Sheppard, who was responsible for launching a number of large ships. He wished the author of the paper just read would add to it some data as to the distance in which ships could be brought up after launching. This question became of importance when the Invincible class were being built, and before placing the contracts the Admiralty had to satisfy themselves that the ships could be launched without danger of colliding with the bank opposite the builder's yard. As to the advantages of cambering the ways, it should be noted that in the first place the ship had to be held securely in position until ready for launching. Hence a gentle slope at the upper ends of the ways was advisable. Once started down them, the risk of sticking had to be avoided, and hence the increased steepness given to the lower portion of the ways. This has also the advantage that the stern dipped deeper and became water-borne sooner than if the ways had a uniform slope.

Mr. James Hamilton, who spoke next, said that Sir William Smith had revived for him some old recollections. The accident to the Independencia had been a warning to his firm. In launching the Nelson, they had built up the ship nearly solid with temporary oak packing in the danger zone, but, nevertheless, some of the frames and floors buckled. Had the packing been omitted, no doubt the after end of the ways would have come through the floors, just as happened with the Independencia. The buckling occurred just about the point indicated by their calculations.

Mr. John Smith, who followed, said that one effect of camber had been pointed out in the speaker's paper read in 1899. This was that cambering the ways had the effect of artificially increasing the height of the tide. As the stern tilted downwards, with the camber, it lifted at an earlier stage. Calculation showed the enormous importance of this effect, particularly as vessels increased in size. With double the length, other conditions remaining the same, one ought to have double the height of tide. The same result would, however, be obtained by a camber of one foot in 600 ft. length, which was equivalent to a rise of 9 ft. or 10 ft. in the height of the tide. The author had assumed that the pressure between the poppet and the ways was distributed according to a triangular law; and some assumption of this kind was necessary. The speaker, however, believed that it was incorrect to assume that there could be no tension between the sliding surface of the poppet and that of the ways. Below water, air could not get in between the two surfaces, and there might, he thought, even be tension above water-level. This tension was very considerable and increased the length of run before the vessel lifted. Another interesting point was the amount of dip when the fore poppet cleared the ways. The speaker, treating the matter statically, had arrived at the conclusion that the dip would not exceed the original height of the load line above water. All launching calculations were in fact made on the assumption that dynamic considerations could be neglected. In general, this assumption was on the safe side, but the author's answer showed that this was not always the case and that the dip might be in excess of the height. One reason for this might be due to the tendency of a moving vessel to "squat" by the stern, which, in the case of a vessel being launched, was, in fact, the stem.

In reply, Mr. Hillhouse said that the story of the Nelson was new to him, though as a boy he had seen the launch from the opposite side of the river. Some years ago his firm were asked by another whether they had had any trouble from tipping, and, forgetful of the Nelson, had replied in the negative, but advised their correspondents not to risk it. The latter, however, took the chance,

AMERICAN COALING STATIONS FOR LOCOMOTIVES.

(*For Description, see opposite Page.*)

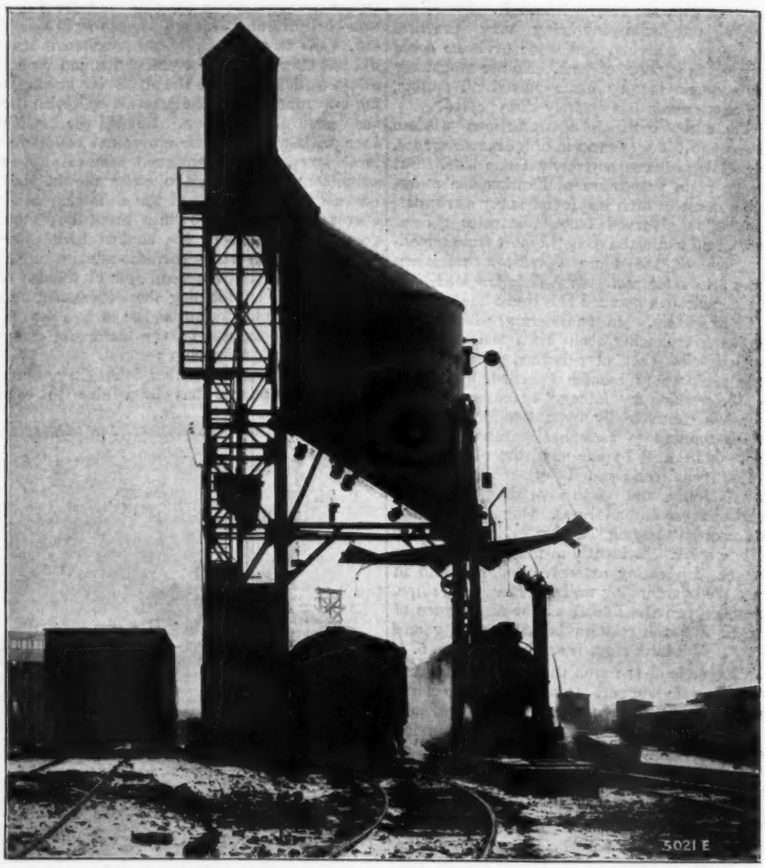


Fig. 13. Helmen Coaling Station at Waukegan, Illinois.

AMERICAN COALING STATIONS FOR LOCOMOTIVES.

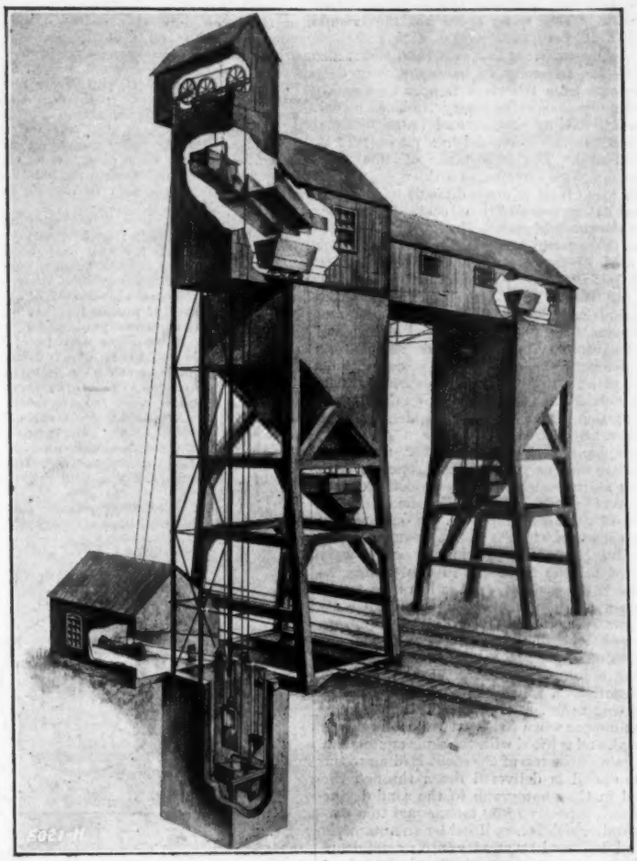


Fig. 16. Typical Two-Pocket Coaling Station.

and the vessel did tip, the forepart rising out of the poppet, but without damage. In reply to Sir William Smith he might say that he had examined many data to devise a rule for the distance in which a vessel could be brought up after launching. The energy due to the fall of the vessel from her initial position on the ways to her final position afloat was approximately proportional to

$$L \times \omega \times W$$

where L was the length of the ship, ω the declivity of the ways, and W the weight. The retarding force was proportional to the weight D of the drag chains, and to the distance d through which they were dragged, so that the ratio

$$\frac{L \times \omega \times W}{D \times d}$$

should be fairly constant. The results were somewhat irregular, but the value of this expression was in the neighbourhood of 600. With respect to Mr. Smith's remarks on the equivalence of increase of camber and rise of tide, this was almost exactly in accord with the speaker's own results as plotted in Figs. 2 and 2A of his paper. The suggestion that tension might exist between the ways was new to him, and he found it difficult to imagine a tension between two surfaces connected only by tallow.

Submarines.

A paper on "The Buoyancy and Stability of Submarines," by Professor W. Hovgaard, had to be taken as read owing to lack of time. It is reprinted on page 346 of this issue, together with a note on it contributed by Colonel Laurenti, of the Italian Navy.

The proceedings were then concluded.

AMERICAN INSTALLATIONS FOR COALING LOCOMOTIVE ENGINES.

By George Frederick Zimmer, Assoc.M.Inst.C.E.

Coaling locomotives by mechanical appliances presents the same difficulty as is experienced when designing a coal-handling plant of a small capacity which must, however, be able to handle large or "run of mine" coal. It is not intended to imply that railway coaling installations are not sometimes of large capacity, but as a rule the difficulty is this, that the coal used is so large that ordinary elevators and conveyers which will accommodate these large lumps are of capacities sometimes four or five times greater than would be necessary for the same weight of smaller coal. This difficulty is sometimes overcome by employing a pair of crushing rollers at the coal tip end of the installation to reduce the size of the coal, so that the largest pieces will be small enough to enter the door of the locomotive firebox. This plan has been followed in all the mechanical coaling stations so far erected in this country, i.e., at Crewe and Camden Town, on the London and North-Western Railway,* and the latest on the North-Eastern Railway at Dairycoates, near Hull. The breaking-up of the coal by rollers produces necessarily much small, while there is hardly any dust produced if the stoker breaks up individual extra-large lumps with his hammer on the engine in the old-fashioned way. The fireboxes of all our locomotives are constructed to burn coal in large pieces, the grate arrangements and the draught being fixed and unalterable on the road, and the draught is sufficient to lift small coal, or a good deal of it, off the grate and carry it away through the tubes unburnt. There is consequently a disadvantage in breaking the coal prior to elevating it into the bunkers, and on the other hand there is also a disadvantage in handling comparatively small quantities of large coal in the ordinary coal-handling machinery, because the initial cost for the larger machinery is out of proportion to the ton-per-hour capacity.

The main reason for this difficulty may be sought in the usual employment of conveyors and elevators, or a combination of the two, in fact a continuous type of conveyor, where the intermittent type would have solved all the difficulty. If we have to handle, say, one ton of coal in five minutes, and put this all in one large receptacle which must be plenty big enough to hold the very largest pieces, we can raise and empty this once in every five minutes, while if we spread this ton of coal out in a continuous and unbroken stream, during a period of five minutes, we must either break it up or we must make the conveyor of a reasonable size for its load.

In the United States, where some of the "run of mine" coal is extra large, gravity bucket conveyors or ordinary bucket elevators have been used in which the buckets were designed to accommodate these very large pieces, and perhaps it was this fact which led to the opening of the eyes of the engineers to the mistaken policy of using continuous conveyors and elevators, and which culminated in the introduction of intermittent systems.

The latest system, as it is employed in the United States for coaling locomotives, is by no means a new idea, its progenitors have been and are in fact still used. They are known as "skip hoists" in this country, and the first which came to the writer's notice were used in the earliest mechanically equipped granary in England, namely, that at the Liverpool Docks, built in 1868. The wrought-iron tipping-skip, holding about one ton of grain, is slung from the lifting chain by an arrangement of bars and levers provided with guiding rollers running between upright timber guides which are so arranged that on arriving at the top the bucket tips over automatically and discharges its load into a hopper. For this purpose an ordinary bucket elevator would have been infinitely better, but the installation was designed at a time when mechanical handling of grain and similar materials was yet in its infancy. The most frequent use in the present day for these "skip hoists" is for handling ashes from large boiler installations ashore or afloat. For this purpose they are unsurpassed by other mechanical conveyers, as the ashes and clinkers, which are generally wet, are not only of a cutting nature, but have also a corrosive influence upon all mechanical parts with which they come in contact, and cannot therefore be economically conveyed in ordinary conveyors, while this cannot do much damage to the skips, which are, moreover, much easier to repair or replace.

The "skip hoist" type of locomotive coaling station, which is making great headway in the United States, is built on the same underlying principle as these ash "skip hoists," a type which in itself appeals on account of its great simplicity, small initial expenditure and cost of maintenance, and its immunity from breakdowns.

What is known as the "Holmen" or balanced bucket system has been developed by the Roberts and Schaefer Company, of Chicago; with this the coal is handled in buckets holding from one to two and a half tons. These buckets are sometimes operated in pairs, so that one counterbalances the opposite one, or a single bucket may be used with a counterbalance weight; the latter is the more generally used arrangement at the present time.

The coal is received in the usual way and dumped into a receiving track hopper below the rail-level. An automatic feeding device is installed between this track hopper and the skip hoist proper; this will hold a charge equal to the contents of the large buckets without overfilling. The skip hoist usually operates in a vertical shaft, and when lowered engages the automatic feeder, which in turn discharges its load into the bucket or skip. The arrangement of this feeding device is such that during its discharge into the bucket the communication with the track hopper is cut off. The bucket is not of the usual tilting-skip type, but discharges by a large hinged door, which is forced to remain closed during the ascent by the rollers on the door, which run on guides at the front of the shaft. As soon as the bucket reaches the top of its ascent the rollers follow a bend in the guides, which now permit the door, formed in the shape of a shoot to open, and the load is discharged into the bunkers. When the bucket descends the door is again automatically closed by the same rollers.

The earliest installation of this type required the constant attention of an operator to reverse the machinery at the termini, whether the plant was operated by an electric motor, steam, or gasolene power. In the subsequent development of such installations it was found expedient that the machines should work automatically, leaving the operator free to dump coal or to attend to the oiling of the machinery. This led to the introduction of an automatic reversing skip hoist controller for operating the motor. When this arrangement is fitted, all that is necessary to start the machinery is to push a button, which energises a magnet on the controller. One end of a plunger in the magnet

* The Edgehill installation, being entirely worked by gravity, requires no elevator of any kind.

or solenoid is carried into a dash-pot. When, therefore, the magnet is first energised it requires several seconds for the plunger to operate and complete the electric circuit to the motor. This period of time may be regulated from 5 to 15 seconds, giving ample time for either the bucket to receive its load at the lower or discharge it at the upper terminus. At the top of the elevator are three switches, one for slowing-down, one for stopping, and one for starting. The bucket ascends at the rate of 140 ft. per minute; when it strikes the slowing-down switch resistance is thrown into circuit, reducing the speed to about one-half; the bucket then proceeds slowly till the stopping and starting switches are engaged simultaneously. The stopping switch arrests the motor, while the starting switch only energises the magnet coil on the controller in the reverse operation. This leaves the bucket at its highest position for several seconds to discharge its load before the circuit to the motor is completed, when it starts on its descent. Thus the machinery continues to operate alternately in its forward and reverse motions until the current is finally cut off by the main switch.

In cases where no electricity is available petrol or steam power can be used, and then the automatic reversing hoist is driven by belt from the engine through a series of cams and clutches, so that the engine may run continuously in one direction, while the hoist reverses automatically at either terminus, leaving also, as formerly, a sufficient period of time for the receipt or discharge of the coal. In the United States locomotive coaling stations on the balanced bucket system are in use where the bucket holds as much as 15 tons at a charge.

For taking the coal from the bunkers to locomotives the undercut gate feeder has been found to be the best method, as there is no blocking of the gate opening when large lumps are present in the coal pocket. The Roberts and Schaefer Company have recently developed, in addition to the ordinary undercut gate and apron, a measuring device which delivers a fixed quantity of coal, say 40 cub. ft., or approximately 1 ton with every charge, and provides a check on the record of coal taken. All our own mechanical coaling stations employ devices on similar lines.

An installation of the class with which we are dealing, which is electrically driven, is shown in Figs. 1 to 3 on Plate XXXI, giving front and side elevations and plan. The structure, which is one erected at Waukegan, Illinois, is entirely of steel and therefore fireproof. The bunker or pocket has a capacity of 300 tons of coal, the skip bucket holds a charge of 2½ tons of "run of mine" coal and is fed at the lower terminus by an automatic revolving feeder, which also discharges 2½ tons at a time. The hoist makes about 24 to 25 trips per hour, and has therefore a capacity of about 60 tons per hour. The illustration shows the feeder in its discharging position. It revolves on trunnions through an arc of about 90 deg. It will thus be seen that when in its starting position it is open and in communication with the track hopper, and when turning into the delivery position it automatically cuts off the supply from that hopper. In order to give the necessary gradient to the track hopper and feeding device for the coal to run it is necessary to have an underground pit 21 ft. deep. The track hopper is 30 ft. long, and will thus permit a very large truck to unload, but if such a hopper is entirely filled it will not empty completely without trimming, so that the coal is preferably dropped in the centre of the hopper in order that it may run down without trimming. Two locomotives on two adjacent tracks can be coaled at the same time.

A very similar installation to that just described, also erected at Waukegan, Illinois, for the Elgin, Joliet and Eastern Railway, is shown in Fig. 13, page 344. It has a single counterbalance bucket hoist and a bunker with a storage capacity of 100 tons of coal and 8 tons of dry sand, the elevating capacity is 40 tons per hour, and the plant is electrically driven; the skip hoist raises the sand similarly to the coal at intervals.

A coaling installation on the same principle, but with the structure entirely of ferro-concrete, is shown in Figs. 4 to 8, Plate XXXI. It has a bunker capacity of 100 tons, and was erected for the National Railway of Mexico-Paredon, at Chihuahua, Mexico. The installation is for one receiving and one delivery track. The feeding device is like that in Fig. 1, but for intermittent charges of 1½ tons only, and the plant is driven by steam instead of by electricity. In this case the coal is paid out from the bunker into an intermediate weigh-hopper, hung on scales, which holds 15 tons at a time and has a registering device which records each draught of coal taken to locomotives. The construction of the hoist shaft may be seen from the plan, Fig. 6; it has a separate compartment for the balance-weight, which is also of ferro-concrete. The elevating capacity of this plant is 35 tons per hour, and the receiving hopper is 20 ft. long. Details of the construction of the tower will be seen in Figs. 7 and 8, Plate XXXI.

The illustrations Figs. 9 to 12, Plate XXXI, show an installation entirely constructed of timber. It was erected for the Chesapeake and Ohio Railway Company at Paintsville, Kentucky. In this case greater width was available, as the tracks for the locomotives to be coaled were sufficiently far apart to permit the structure between, and also the track on which the coal arrives. This wider space has the twofold advantage that it permits a pocket with a 300-ton capacity in a comparatively low structure, and it also dispenses with the necessity of having a very deep pit, since the coal from the track hopper to the skip can be handled by a short auxiliary tip-hoist loader. The track hoist, feeding device, and lower terminal of the hoist are thus all contained in a pit only 12 ft. below the rail-level. The importance of this comparatively shallow pit is obvious, as with an excavation of from 20 ft. to 25 ft. it is often difficult to keep the water out—not to mention additional cost. To transfer the coal from the track hopper to the hoist a ¼-in. steel undercut gate is used which runs on rollers and which admits the coal to the auxiliary skip hoist loader. This gate controls the flow of the coal and is actuated by the moving load. The hoist has a differential action, with a ratio of travel of 5 : 1 for loader and elevating bucket. The former is geared direct and definitely to the automatic hoist, which likewise controls the hoisting bucket. The latter has a capacity of 2½ tons. The plant is driven by a steam winch. The photographic view, Fig. 14, page 352, shows the Greensbury Coaling Station, which is practically identical with that of the plant last described.

The photographic view, Fig. 15, page 352, represents one of the latest designs in reinforced concrete locomotive coaling stations, which was completed only a few months ago at Cowan, Tennessee, for the Nashville, Chattanooga and St. Louis Railway. It embodies a few new features, one of which is the employment of the patent "R. and S." coal-measuring device already mentioned, used for the first time in this plant. In the few months it has been at work it has been found that the accuracy of the measuring comes within 1 per cent. of the correct weight, which is sufficiently accurate for the purpose intended, viz., the knowledge of the relative amount of coal delivered to each locomotive. Another special feature of the plant is an automatic sand-drying installation, which can be seen just in the rear of the hoisting tower. Green sand is dumped into the same track hopper when the hoist is not employed for handling coal, and is lifted with the same equipment. By opening a gate at the top of the shoot leading to the coal pocket the sand is delivered down through the shoot indicated in the photograph to the sand-drying plant. This has a capacity of 50 tons, equal to a carload of green sand, which is here dried by an automatic steam dryer and delivered by gravity into a sand drum beneath the drying station, from where it is forced up by compressed air into the dry sand bins over the coal pocket, ready to be delivered to the locomotives at the same time as they are taking coal. Taken as a whole, this illustration is a good example of the most up-to-date practice in locomotive coaling and sanding facilities in the United States of America

A typical two-pocket coaling station is illustrated in Fig. 16, on page 345. This installation has one pocket at each side of two main line tracks. Where a coaling station must be divided, due to track arrangements, as in this case, and where it is necessary to transfer the coal from one side to the other, the automatic tram-car system has been found very satisfactory. To manipulate this a double drum hoist with cable is used for operating the hoisting bucket, the cable is wound on one drum and that for operating the tram-cars on the other, the drums being of diameters relative to the travel of hoisting buckets and tram-cars respectively. The tram-cars are hopper-bottomed, and are emptied by a tripper arrangement which opens the bottom at a predetermined spot and thus deposits the coal at any desired point over the pocket. Fig. 16 also shows two 12-ton weighing pockets suspended beneath the main coal pockets for weighing each discharge of coal delivered to the locomotive. This method of paying out the coal has been very popular in the United States, but seems likely to be superseded by the measuring devices, as they are less expensive and sufficiently accurate.

THE FLYING MACHINE FROM AN ENGINEERING STANDPOINT. ERRATUM.—By a slip of the pen Mr. Lanchester's "James Forrest" lecture on flying machines was, on page 313 of our last issue, said to have been delivered before the Institution of Mechanical Engineers instead of the Institution of Civil Engineers.

TUNGSTEN AND MOLYBDENUM STEELS.—A report issued by the French Société Electro-Chemique du Giffre indicates that radical changes are taking place in the manufacture of special steels, and that the use of tungsten steel is increasing every day, fresh applications being continually investigated. Molybdenum is likely also to play an important part in the manufacture of special steels. Although the prices of wolfram and molybdenum are expected to decrease somewhat, it is practically certain that they will not return to pre-war levels.

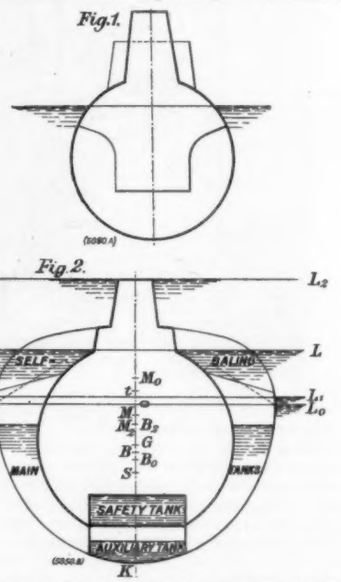
BUOYANCY AND STABILITY OF SUBMARINES.*†

By PROFESSOR WILLIAM HOVGAARD.

THE object of this paper is to give a discussion of some of the more important problems connected with the buoyancy and stability of submarines. It is attempted, in particular, to disentangle the somewhat complicated relations between buoyancy, weight and stability, and to discuss in a general way the means which must be adopted to control these qualities. A mathematical and graphical mode of representation is proposed with a view to a standardisation of ship calculations for this craft. It is hoped that the paper may elicit criticism and additional information from designers as well as from naval officers who are familiar with the handling of submarines, so that further light may be thrown on this important subject.

From the point view of buoyancy and stability submarines differ radically from ordinary vessels on account of the requirements for wide and rapid changes in displacement, ranging from a surface condition with considerable reserve buoyancy to a state of complete submersion. This necessitates the use of a number of ballast tanks with powerful means for flooding and pumping, and gives rise to some complicated problems in buoyancy and stability. Submarines may be classified as single-hull and double-hull boats, which differ in the mode of construction and therewith in point of stability and mode of subdivision. The differences in the latter respects, although very considerable, are, however, essentially of a quantitative nature only. Both types must be subdivided on the same principles; the claims to stability in the various conditions are the same; and the same method of representing the buoyancy and stability, mathematically as well as graphically, may be employed.

Figs. 1 and 2 show diagrammatic sections of a single-hull and a double-hull boat respectively. In the former



the ballast-tanks are entirely inside the strength-hull, in the latter they are chiefly outside. Between these two extremes, intermediate types exist. The general discussion of buoyancy and stability, with which the paper begins, covers both types, but we refer in particular to the double-hull boat and hence to Fig. 2, because it presents the most complete and complicated case.

WEIGHT AND BUOYANCY.

We may regard all ballast-water, internal or external, and water in self-baling parts as forming part of the sea and, hence, as not belonging to the weights of the boat. It follows that the buoyant volume changes form and the centre of buoyancy changes position when ballast-water is pumped in or out, but the displacement and the position of the centre of gravity remain unaltered under all the various conditions of immersion so long as no other weights are added or withdrawn. This is found to simplify the treatment very considerably.

Normal Conditions.—In the designed condition the boat is supposed to be ready for sea, but with only a certain part—say two-thirds—of the fuel and other consumable weights on board. We assume that the fuel is oil, and that the vacant volume in the fuel-tanks is replaced by sea-water; but this water, which is not expelled when the boat is in the light condition, is not regarded as ballast, and is, like the fuel-oil itself, reckoned to belong to the weights of the boat. The water in which the boat floats is supposed to be of a certain normal density, which should be the average of that of the sea in which the boat is destined to operate. The term "normal" is applied to all conditions where the

* Paper read at the Institution of Naval Architects, March 29, 1917.

† Proof uncorrected by author.

loading of the boat and the density of the sea-water are as here defined, irrespective of the water-line on which the boat may float, since that depends only on the amount of ballast-water admitted into the tanks.

Various Conditions of Floating.—Referring to Fig. 2, the water-line and conditions to which a boat may be brought by means of water-ballast are defined as follow :—

$W_0 L_0$: "Light condition," in which all ballast-water is expelled. So long as the loading of the boat and the density of the sea-water remain unaltered, the boat cannot float on any lighter water-line than $W_0 L_0$.

$W_1 L_1$: "Ready-to-dive condition," in which filling of the main ballast-tanks will just submerge the boat and give her the proper trim for going under water.

$W_2 L_2$: "Submerged condition," in which the boat is fully immersed. There remains usually, when the boat is under way, a slight excess buoyancy, which is overcome by means of the horizontal rudders ; but this buoyancy, which is ordinarily not more than about 1 lb. per ton of the displacement, may here be neglected. Longitudinally, the boat is assumed to be in equilibrium with its axis about horizontal.

W L : Any condition intermediate between light and submerged conditions.

3. The net volume of all ballast tanks, which are normally either completely full or completely empty, *i.e.*, all the main tanks, to which also the so-called safety tank is reckoned to belong. It is immaterial to this grouping whether the tanks are internal or external.

4. The net volume occupied by water in the partly filled ballast-tanks when the boat is submerged. In order to avoid heavy scantlings, these tanks are usually fitted inside the strength-hull, but, again, it is immaterial to the mode of grouping whether they are internal or external.

5. The net volume of all self-baling parts above the light water-line, $W_0 L_0$, often referred to as the superstructure. In some boats these parts may be closed watertight so as to contribute to reserve buoyancy in light condition after the water has run off, but in the submerged condition they are always filled with water. We shall assume them to be flooded up to the plane of flotation. The self-baling superstructure is not exposed to heavy pressures and may be lightly built.

Definitions.—Referring again to Fig. 2, the following symbols are used, where necessary, with suffixes corresponding to the water-lines to which they belong.

G : Centre of gravity of the boat complete, but exclusive of all water-ballast. This point remains in the same position under all conditions of immersion, so long as no weights belonging to the boat are removed and no extra weights, other than water-ballast, are added.

B : Centre of buoyancy of total displacement volume below the plane of flotation, excluding net volume of all water-ballast actually in the tanks and of self-baling spaces flooded above $W_0 L_0$.

V : The always-buoyant volume below the water-line, *i.e.*, that defined under (1) and (2). We do not, therefore, include in V the vacant spaces that may exist in the main tanks prior to or during flooding, nor those which may exist in other tanks below the level to which they are flooded in submerged condition, *i.e.*, no volume comprised in groups 3 and 4 is included in V. When the boat is fully submerged $V = V_2$, which—under the assumption that no excess buoyancy remains in that condition—is equal in amount to the effective buoyancy-giving volume or the "displacement volume" on all water-lines at which the boat may float. This volume is constant so long as the loading of the boat and the density of the sea-water remain unaltered.

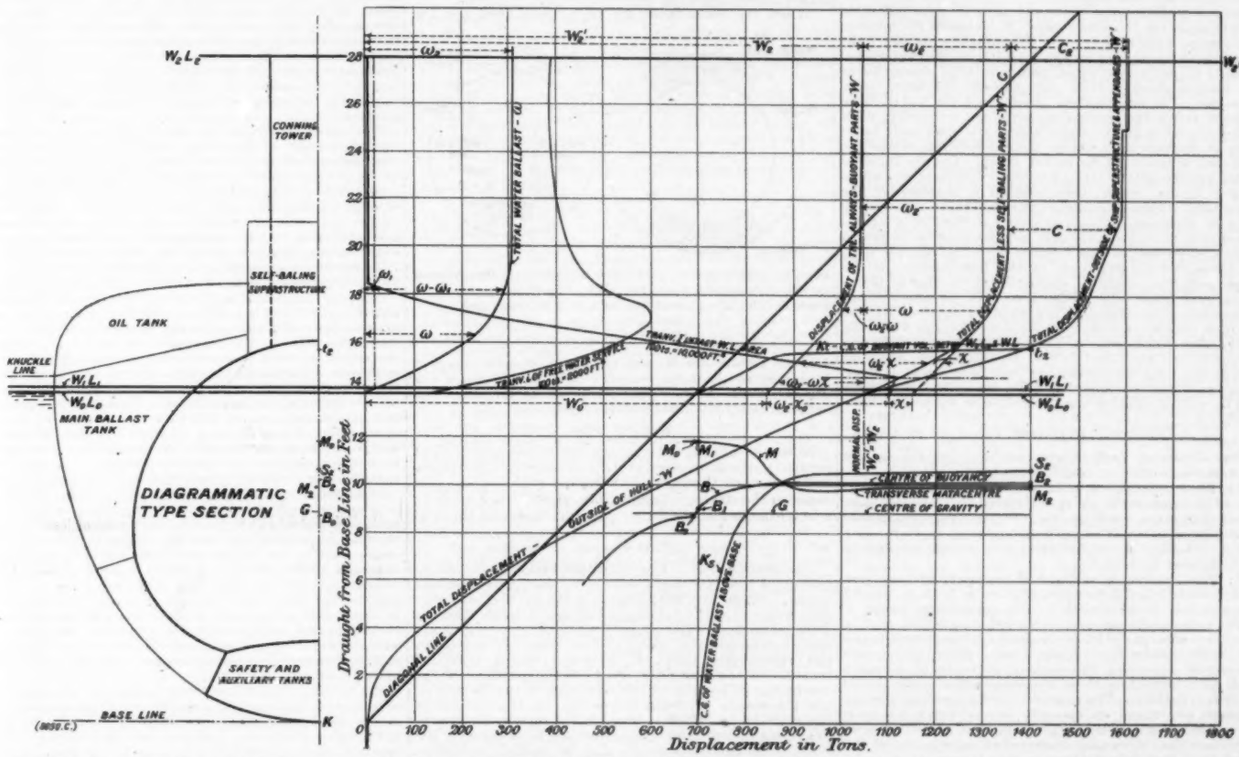
v : The volume of all ballast-water actually in the tanks when the boat floats on any water-line, W L. In the light condition $v = 0$. In the ready-to-dive condition $v = v_1$, which is the volume of water admitted to all tanks other than the main tanks. In the submerged condition $v = v_2$, which is the maximum amount of water-ballast, but does not include the water which may be found in the oil-tanks. In this condition the main tanks are filled completely while other tanks are only partly flooded. The aggregate volume of the main tanks is accordingly $v_2 - v_1$. The total tank volume v_2 is equal to the reserve buoyancy in the light condition, and is in modern double-hull boats ordinarily from 25 to 35 per cent. of the light displacement. In single-hull boats it is now usually from 15 to 25 per cent. of the light displacement. In the reserve buoyancy is often included the volume of the self-baling superstructure in so far as it can be made watertight, and this explains the very large percentage of reserve buoyancy given for certain boats.

c : The volume of water that has entered the self-baling spaces above $W_0 L_0$ when the boat floats on any water-line, W L. The self-baling spaces below $W_0 L_0$ which belong to group 2 are included in V, as explained above. It follows that $c_0 = 0$.

V' : The total or gross volume contained inside the external bounding surface of the boat, including appendages and reckoned up to any given water-line, W L. It is the aggregate of all the volumes enumerated under (1), (2), (3), (4) and (5). In the light condition $V' = V'_0$, which is equal to the constant displacement volume. In the submerged condition $V' = V'_2$, which comprises the entire volume contained within the external surface of the boat.

x : The volume of that part of the tanks—usually the main tanks—which is above any given water-line. In the light condition, x has its maximum value, and is equal to x_0. When water is admitted into the tanks, and the boat begins to sink to a deeper draught, x ultimately becomes zero, and will vanish in many boats before the ready-to-dive condition is reached, depending, of course, on the height to which the tanks are carried. In some boats x is zero even in the light condition.

Fig. 3. DISPLACEMENT AND OTHER CURVES. DOUBLE-HULL SUBMARINE.



Analysis of the Displacement Volume.—The total volume bounded by the external surface of the boat when it is fully submerged may be divided into several parts, each of which has its special function in the buoyancy problem, and which must be clearly distinguished from one another.

1. The volume of the strength-hull, with deduction of the net space occupied by water in the internal ballast tanks when the boat is in the submerged condition. By the term "strength-hull" is here meant that part of the hull which is designed to resist the pressures at the maximum depth of immersion. This volume, in so far as it is below the plane of flotation, always contributes to buoyancy.

2. The volume of all water-excluding parts outside of the strength-hull, including external appendages, structural materials whether inside or outside of the external tanks, anchors, telephone buoy, deck torpedo-tubes with torpedoes, and all other objects external to the strength-hull. In addition, we include in this group also the net volume of the self-baling spaces, which may be found below the water-line in light condition, since these spaces are always filled with water when the boat is afloat. As an example may be mentioned the space forward of the sluice-valves of the torpedo-tubes in the bow, inside the ports, between the stem and the first bulkhead. Other similar spaces, which bale out only when the boat is in dry dock, may be found. The volume of all such spaces is generally small, and is included in this group simply as a matter of convenience ; the water which fills it is considered as belonging to the permanent weights of the boat.

The sum of all volumes under groups 1 and 2 is often referred to in the following as the "always-buoyant volume." This volume is, of course, effectively buoyant only when below the plane of flotation.

The weights of the water of normal density that would fill the spaces V, v, V', c, and x are denoted respectively by W, w, W', C, and X. These weights are here supposed to be given in tons, and the volumes in cubic feet.

Relations between the Different Weights and Volumes.—On any given water-line the total displacement is equal to the sum of all its component parts :

$$\left.\begin{aligned} W' &= W + w_2 - X + C \\ V' &= V + v_2 - x + c \end{aligned}\right\} \quad . \quad . \quad (1)$$

The weight of the boat remains unaltered under all conditions of immersion, being independent of the ballast-water. This weight is the constant "displacement," and must be equal to the displacement in the light condition, W_0, as well as to the effective buoyant displacement in submerged condition, W_2. Hence :

$$\left.\begin{aligned} W_0' &= W_2 \\ V_0' &= V_2 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

On any water-line the always-buoyant volume plus the spaces remaining to be filled in the tanks minus that part of the tanks which is above the water-line must equal the constant displacement volume :

$$\left.\begin{aligned} W_0' &= W + w_2 - w - X \\ V_0' &= V + v_2 - v - x \end{aligned}\right\} \quad . \quad . \quad (3)$$

The weight and volume of ballast-water that has entered the tanks must always be equal to the weight and volume of the buoyant displacement added

above $W_0 L_0$:

$$\left.\begin{aligned} w &= W - W_0 + X_0 - X \\ v &= V - V_0 + x_0 - x \end{aligned}\right\} \quad . \quad . \quad (4)$$

When the top of the tanks becomes immersed X and x disappear from the equations. In the submerged condition the equations (4) may be written:

$$\left.\begin{aligned} w_2 &= X_0 = W_2 - W_0 \\ v_2 &= x_0 = V_2 - V_0 \end{aligned}\right\} \quad . \quad . \quad (4')$$

showing that the tank volume below $W_0 L_0$, which is occupied by water in submerged condition, must be equal to the total always-buoyant volume above that water-line. The volume v_2 comprises x_0.

The total displacement up to any water-line minus the self-baling parts must always be equal to the normal displacement plus the weight of ballast-water actually in the tanks:

$$\left.\begin{aligned} W' - C &= W_0' + w \\ V' - c &= V_0' + v \end{aligned}\right\} \quad . \quad . \quad . \quad (5)$$

Tank Volume above the Water-line.—The tank volume here denoted by x, which exists as such only so long as it is above the water-line, is inactive in so far as it does not contribute to buoyancy. In the submerged condition this volume is again inactive, because it is filled with water. Whether x_0 is large or small, condition (4′) holds good.

The existence of tank volume above the water retards immersion and emersion, since it increases the amount of water that has to be admitted into or expelled from the tanks. On the other hand, it increases the reserve buoyancy, and it improves the stability in the light conditions by adding to the breadth of the water-line. This is of particular value when the boat enters water of smaller density than the normal and when it is damaged. In intermediate conditions the extra tank volume below the water-line, while yet unflooded, adds buoyancy at a great height above the keel and helps thus to increase the stability under conditions where the stiffness is liable to be rather small. Let us consider what happens if the tanks are lower so as not to extend above $W_0 L_0$, while their breadth is increased. The same tank volume and, hence, the same reserve buoyancy may be obtained. The boat comes to float on a lighter draught in the light condition, but the moment of inertia of the water-line will be reduced with the circular form of strength-hull, and that of the free surface in the tanks will be increased. Moreover, the centre of buoyancy, and hence the metacentre, will be lower in all intermediate conditions. The result, therefore, will be a much lessened stability in the critical stage while the tanks are being filled. This defect may indeed be remedied, as explained below, by fitting oil-tanks on top of the main ballast-tanks; but unless that is done it appears best to carry the main tanks well up above $W_0 L_0$ with a slanting top, as indicated by dotted lines in Fig. 2.

STABILITY.

The following further symbols and definitions are introduced:—

I: The transverse moment of inertia about the centre-line of the area of the plane of flotation. This area comprises that intercepted by the strength-hull, by external oil-tanks, whether filled with oil or water, and all other water-excluding parts, but does not include self-baling parts flooded by water.

i: The transverse moment of inertia of the net free water surface in the tanks. When a tank is placed symmetrical with respect to the centre-line plane or when a tank on one side is in free connection with a tank on the other side, the moment of inertia is taken about the centre-line of the boat. When side tanks are not so connected, the moment of inertia is taken for each tank separately about the longitudinal neutral axis of its free surface. The connection which actually exists between two tanks on opposite sides through the open sea-valves during flooding or expulsion of water, is so imperfect that it can be disregarded on account of the short duration of the process.

s_2: The centre of gravity of all the water-ballast, w, actually present in the boat on any water-line, W L.

t: The centre of gravity of the corresponding buoyant volume added between $W_0 L_0$ and W L, including the immersed part of the top of the main tanks, $x_0 - x$.

M: The metacentre, with appropriate suffixes.

The metacentric height, which in the light condition is $G M_0$, is in any intermediate condition:

$$G M = G M_0 + M_0 M$$

and

$$M_0 M = B_0 B + B M - B_0 M_0$$

When the tanks are being flooded the space occupied by ballast-water with its centre of gravity at s is replaced by a buoyant volume which always has its centre of gravity, t, at a higher level than s. Hence the centre of buoyancy will always go up when ballast-water is admitted into the tanks, *i.e.*, $B_0 B$ is always positive. Taking moments about the bottom of the keel, K, we have:

$$V_0' \times B_0 B = v (K t - K s)$$

$$\therefore \quad B_0 B = \frac{v \times s t}{V_0'}$$

Further

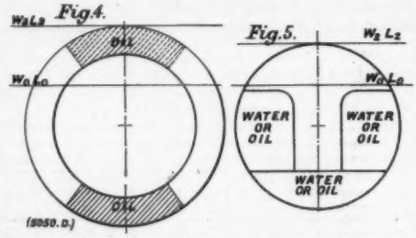
$$B_0 M_0 = \frac{I_0}{V_0'} \quad \text{and} \quad B M = \frac{I - i}{V_0'}$$

whence

$$M_0 M = \frac{v \times s t}{V_0'} + \frac{(I - I_0 + i)}{V_0'} \quad . \quad . \quad (6)$$

When the tanks are flooded and the top of the tanks (the knuckle-line in Fig. 3) becomes immersed, I will fall off very rapidly unless external oil-tanks are fitted in the superstructure, in which case the falling off of the moment of inertia will be more gradual. In single-hull boats I is likewise liable to fall off rather rapidly during the process of flooding. At the same time a free surface exists in the tanks, i may attain a considerable value and may even exceed I. The consequence is that although $B_0 B$ is positive, the last term of equation (6) acquires so great a negative value that $M_0 M$ is practically always negative. Hence, M ordinarily falls below M_0 in all intermediate conditions. The metacentric height decreases to a certain minimum, after which it increases somewhat to the value $G M_2$, when fully submerged. The point where the minimum occurs and its numerical value depends on the form and location of the tanks on the form of the buoyant part of the hull above $W_0 L_0$. It is usual to stipulate a certain positive minimum value of G M, but it appears that in some boats under certain conditions of loading and flooding $M_0 M$ may become equal to or even greater than $G M_0$, in which cases the initial stability vanishes. It does not follow, however, that the safety of the boat is therefore jeopardised. Generally, as the boat heels over, the free surface in the tanks will be reduced, and where tanks on opposite sides are in connection with each other the water will ultimately fill the tank completely on one side and the value of i will then be enormously reduced. Depending on the degree of flooding and on the design of the tanks, the boat will in most cases find a new position of equilibrium at a small or moderate angle of heel. In fact, as far as the author is aware, no case is on record where a submarine has capsized due to this cause.

When the main tanks are completely filled and the



boat is submerged, i will have a value, i_2, determined by the free surface in the tanks other than the main tanks. The moment of inertia I will be zero, and

$$B_2 M_2 = -\frac{i}{V_0'}$$

i.e., the metacentre M_2 will fall below B_2, the centre of buoyancy of the total buoyant volume, but since i is usually small, the two points will not be far apart and approximately the metacentric height—

$$G M_2 = G B_2$$

In this condition the longitudinal metacentric height is equal to the transverse, $G M_2$. The centre of buoyancy will have risen through a distance—

$$B_0 B_2 = \frac{v \times s_2 t_2}{V_2}$$

THE TANKS.

The Main Tanks.—The main tanks serve to effect the transition from the ready-to-dive to the submerged condition. When the boat floats on $W_1 L_1$, the ready-to-dive water-line, the flooding of all tanks other than the main tanks is so adjusted that when the main tanks are filled completely the boat will just submerge and be on the appropriate trim. It is worth noting that the location of the water-line $W_1 L_1$ is independent of the conditions of loading of the boat and of the density of the sea-water. It depends entirely on the volume of the main tanks, which is equal to the reserve buoyancy. $W_1 L_1$ may, therefore, with advantage be painted on the boat, or conspicuous marks may be painted amidships and at the ends in order to facilitate placing the boat on this water-line prior to diving. The main tanks should constitute by far the greater part of the total tank volume; in fact other tanks should not be greater than necessary to allow for variations in weight and buoyancy, as explained below, and will always be relatively small. It follows that the water-lines $W_0 O_0$ and $W_1 L_1$ will not be far apart under normal conditions. The main tanks should normally be either completely empty or completely full; a free surface should exist in them only during the process of flooding or emptying, which, for military reasons, should be capable of being accomplished in a few minutes.

It has been shown that there are certain advantages in extending the main tanks well up above $W_0 L_0$, and in making them narrow in the upper part. It is otherwise desirable to place the tank volume as low as possible, since thereby the structure enclosing and stiffening the tanks obtains a low position and helps to draw the centre of gravity of the boat down. This is of particular value when the boat is submerged, and in the light condition the large empty tanks under the bottom serve to draw the centre of buoyancy and hence the metacentre down, and thus lessen the stiffness, which is apt to be excessive in double-hull boats in that condition. The main tanks should be well subdivided in a number of separate tanks, especially the side tanks. Those that are located centrally under the bottom can be of larger volume, but if they extend far up the sides they should be subdivided by a vertical watertight diaphragm at the centre line. The main tanks should be concentrated as far as possible towards amidships so as to minimise disturbances of the longitudinal balance.

In certain cases of emerging, as for instance when the boat is damaged or when for some reason it tends to dive below the designed maximum depth, it may be required to produce with certainty a great and sudden force of buoyancy. One way of attaining this object is to carry detachable ballast consisting, for instance, of blocks of lead which can be let go as desired, but this method, which was formerly quite frequently used, has several obvious drawbacks and appears to be now almost entirely abandoned. When lead-ballast is fitted in modern boats it is chiefly for other purposes. The solution now generally adopted is to blow out the water of one of the main tanks specially fitted for that purpose. This tank is called the "safety" or "emergency" tank. It should be located near the centre of gravity of the boat, and should preferably be fitted entirely inside the strength-hull so as to be well protected against damage. It should be able to resist internal pressures at least equal to the external pressures which the strength-hull is required to withstand. The water should be expelled by high-pressure air or, if that is not available, by a special pump capable of working against high pressures. The ordinary main tanks are too large for this purpose and are too exposed to damage; if they are external and lightly constructed, they cannot be emptied by pumps when the boat is at a great depth of immersion. The capacity of the safety tank appears to be rarely more than from one-half to one per cent. of the light displacement. Ordinarily, the safety tank may be operated together with the other main tanks, being empty in the ready-to-dive condition and flooded when the boat is to submerge. In case of emergency, when the boat is at a great depth, the safety tank is blown out first, and afterwards, when the boat has ascended to more moderate depths, the other main tanks are emptied. If an accident happens while the boat is at a small or moderate depth, all the tanks can generally be blown out by low-pressure air, but at very great depths there might not be sufficient compressed air available for this purpose.

The Auxiliary Tank.—If the density of the sea-water and the weight of the boat remained always the same, the adjustment of the buoyancy before diving would be simple and could be made once for all, but in passing from fresh to salt-water, or vice versa, the buoyancy of a given displacement volume may vary more than 2½ per cent. and the weight of the boat may vary considerably, due to the consumption or shipping of oil or other stores, firing of torpedoes and ammunition, &c. It is, therefore, necessary to provide for variations in the amount of ballast-water required to submerge the boat.

Suppose that a boat is designed for service on the ocean, and that she, when in normal condition in water of normal density and ready to dive, floats, as she should do, on the water-line $W_1 L_1$. When, under these circumstances, she enters water of less density or takes on board stores in excess of the normal supply, she will sink deeper into the water, and when going to dive she will submerge before the main tanks are filled. This is objectionable, not only because there will be a free surface in one or more tanks, but still more because the distribution of water in the tanks is indefinite and uncontrollable, so that the longitudinal balance may be seriously disturbed. In order to avoid this it is necessary under normal conditions to carry a certain quantity of water in a special tank, from which the requisite amount can be discharged when the boat enters water of less density. By this means the boat can be brought to the ready-to-dive condition, on $W_1 L_1$, and when the boat submerges the main tanks will be completely flooded whatever the density of the water. The tank provided for this purpose is called the "auxiliary tank." It is placed at the centre of gravity of the boat, perhaps below or enclosing the safety tank. It can thus be operated without affecting the longitudinal balance of the boat, and the free surface which exists in it will be of a definite, known area.

We have to consider, moreover, that the consumption of stores or ammunition reduces the displacement and causes the boat to float on a relatively lighter draught in the light condition. The same happens when the boat enters water of greater density than the normal. Under these circumstances it will be necessary, when making ready to dive, to admit a certain quantity of water into the auxiliary tank in addition to that which, as shown above, must be carried under normal conditions. The tank must, therefore, be of such additional capacity as to allow for these eventualities.

In determining the size of the auxiliary tank, the designer must consider first the probable extreme variations in density of the sea-water in which the boat is destined to operate. Suppose, for instance, that the volume of a ton of water in the sea where the boat is to operate is normally 35.25 cubic ft. per ton, and that this volume is liable to vary from 35 to 35.5 cubic ft. Then the maximum fluctuation in buoyancy for a given displacement volume is about 1½ per cent. A boat of say 1,000 tons normal displacement would be liable to fluctuations in buoyancy from about 993 tons to 1,007 tons. The auxiliary tank must therefore have a capacity of at least about 15 tons, but if the boat happens to be operating in water of maximum density and at the same time stores are consumed so that the displacement falls below the normal, it will be necessary to admit still more water into the tanks when the boat is to submerge. If, however, the consumption of oil-fuel is compensated for by the admission of water, as usually done, there will generally be no deficiency in weight. In general, therefore, the tanks will not need for this reason to be made larger.

When the boat operates in water of minimum density and has more than the normal supply of fuel and stores on board it will be necessary first to pump out the water normally carried in the auxiliary tank to provide for variation in density of the sea-water, and next a weight of water equal to that of the surplus of stores, &c. Probably, however, this weight will be already compensated for by the fact that the extra supply of oil

weighs less than the water which in normal condition takes its place. Hence, under all conditions, the gradual substitution of water for oil compensates more or less for the simultaneous consumption of stores. To this must be added that the trimming tanks, to be described below, afford a further margin for variations in weight. The auxiliary tank, therefore, need not be larger than required to provide for variations in the density of sea-water. It might be argued that the auxiliary tank might be used as safety tank, but on account of its large size and the uncertainty as to its contents it is not so well adapted for this purpose.

Trimming Tanks.—Before diving, the boat must be given the proper trim in conformity with the water-line $W_1 L_1$ of the ready-to-dive condition, and in the submerged condition the longitudinal balance requires occasional adjustments. For these purposes "trimming tanks" should be fitted as near the ends of the boat as possible, and provided with means for pumping water from one into the other. In normal condition these tanks need not hold much water—probably 1 or 2 tons each for every 500 tons of displacement will prove sufficient—but the total capacity should be at least twice that amount, and where they are used as compensating tanks for the torpedoes, as explained below, they require additional capacity according to circumstances.

Adjustment Tank.—An accurate adjustment of the draught and trim in the ready-to-dive condition is often difficult or impossible. Frequently, perhaps in most cases, the wave motion prevents an exact reading of the draught marks, and under war conditions time may not always permit a fine adjustment before diving. Hence, a special process of adjustment is often required in the submerged condition. For this purpose, whether the operation takes place on the surface or after the boat has submerged, a small "adjustment tank" is fitted in some boats near the centre of gravity. By pumping water in or out of this tank with a small pump, it is possible to adjust the buoyancy accurately. Experience, however, seems to show that even considerable irregularities in buoyancy and trim can be allowed for by a proper use of the horizontal rudders. Moreover, from the way the rudders are carried, it is possible to judge of the balance of the boat, and all that is required is to operate on the auxiliary and trimming tanks with a small pump. Thus, the adjustment tank can probably be dispensed with altogether.

Compensating Tanks.—When a torpedo is fired an equivalent weight of water immediately enters the tube and re-establishes the balance of the boat, but in order to insert a new torpedo the water must be blown out of the tube, and if this water be discharged overboard, as also when the torpedo is moved from its stowage position to the tube, the buoyancy and trim are disturbed.

In order to avoid these effects some boats carry special reservoirs into which the water is discharged, placed so that when the new torpedo is inserted and water admitted to the tube the balance of the boat is restored. It appears, however, that this refinement is unnecessary, at any rate in large boats. In modern submarines the water from the tubes is ordinarily discharged into the adjacent trimming tank, which must be for this purpose of somewhat larger capacity. Other changes in weight, occurring in the ordinary routine of the service, usually take place nearer the centre of gravity of the boat; their effects are less violent and may be compensated for by auxiliary and trimming tanks. In fact every effort should be made to reduce the number of tanks to a minimum. Every new tank adds to the complication, weight, and cost of the boat, and opens fresh possibilities for mistakes and breakdowns. When compensating tanks are fitted, the water which they contain should be reckoned to belong to the weights of the boat.

The Oil-tanks.—The fuel-oil represents such an enormous weight that its consumption can only be compensated for by filling water in the empty oil-tanks. Where the tanks are fitted outside the boat and lightly constructed, as appears to be the case in the German boats, it is necessary to replace the oil by water completely and gradually by drawing water into the tanks as fast as the oil is removed, so that all the tanks shall always be filled and under the same pressure as the external water. If the tanks are internal, or if they are strong enough to withstand the maximum external pressures, the tanks may be flooded by water successively as they become empty, but in such case the individual tanks must be of small size. Since the density of oil is smaller than that of water, generally not more than about 0.9, the substitution of water for oil will result in an addition to the weight of the boat equal to at least 10 per cent. of the weight of oil consumed. If, for instance, a boat carries a supply of oil equal to 10 per cent. of the displacement, the addition in weight after consumption of say one-half of the oil would be 0.5 per cent. of the displacement or about 5 tons in a 1,000-ton boat. As stated above, this excess weight is at least partly counterbalanced by the consumption of stores which always takes place at the same time, and the auxiliary trimming tanks should be able to provide for the difference.

It is of importance to investigate whether, from the point of view of stability, the oil-tanks should be placed high or low in the boat. It appears that in the German U-boats the oil-tanks are placed externally on top of the boat, while in many other types they are placed in the bottom. The problem is best studied by considering simple cases. Fig. 4 represents the section of a double-hull boat constructed of an inner strength-hull of circular section and an outer concentric lightly built hull. The space between the two shells is used for water-ballast except where it is occupied by oil. An oil-tank in the bottom is shown in full and the alternative of an oil-tank in the top is shown dotted. Consider first the submerged condition. By raising the oil-tank from the bottom to the top the centre of gravity will go up, but the centre of buoyancy, in this case the metacentre, will move up still more, so that the metacentric height will be somewhat increased. In the light condition the boat will float on the same water-line, $W_0 L_0$, whether the oil is placed high or low, and the centre of buoyancy as well as the metacentre will be in the same position in both cases, but with the high stowage of the oil the centre of gravity will move up through a considerable distance, whence the metacentric height will be correspondingly reduced. Now, double-hull boats have usually rather small stiffness in the submerged condition and too great stiffness in the light condition, whence the effects of placing the oil-tanks in the upper position are entirely beneficial. In intermediate conditions, while the ballast-tanks are being flooded, the oil-tanks will increase the moment of inertia of the water-line and with proper design they will help to avoid any dangerous reduction in the stability. In double-hull boats oil-tanks should, therefore, be placed in the highest possible position, preferably in the superstructure above the main tanks. These latter should be very deep in the centre, rather narrow on the sides, and should not extend much above the normal light water-line. They should be concentrated as far as possible towards amidship, leaving the ends of the boat with single shell. As far as the disposition of the main tanks is concerned these conditions seem to be most nearly realised in the Laurenti boats.

Single-hull Boats.—In single-hull boats of the pure type all ballast and oil tanks are inside the strength-hull, but the same tanks must be fitted as in double-hull boats and for the same purposes. Again, V signifies that part of the always-buoyant volume which is below the water-line. The volume occupied by ballast-water is denoted by v, and is reckoned to belong to the sea. Usually the ballast-tanks do not reach above the water-line, so that the space x does not exist, but otherwise the same symbols are used with the same meaning as for double-hull boats.

The effects of placing the oil-tanks in a high position as compared with a low position are the same as in double-hull boats. Fig. 5 shows a section of a single-hull boats with side tanks and a bottom tank. By carrying the oil in the bottom and the water-ballast in the side tanks the metacentric height, as compared with the converse arrangement, will be slightly reduced in the submerged condition but much increased in the surface condition. Since single-hull boats are usually amply stiff when submerged, but rather crank in the surface conditions, it seems best to store the oil in the bottom in this type of submarine.

Displacement and Other Curves.

In order to obtain an accurate and complete knowledge of the buoyancy and stability in the various stages through which a submarine has to pass during the transition from the light to the submerged conditions, it is necessary to construct a number of curves as on the diagram, Fig. 3, which was prepared in connection with the design of a large sea-going double-hull submarine. For the sake of clearness only the curves which have a direct bearing on the foregoing discussion are shown.

The diagram is worked out for normal condition of loading and normal density of sea-water. The curves for W, W′, C, I, and i are plotted on a vertical draught scale as base, the ordinates being set off horizontally along the respective water-lines on which the boat is floating. From the curve for W′, the gross displacement, the values of C, the weight of water that has flooded the self-baling parts, is set off inwards, towards the vertical base-line, and thus a curve for $W' - C$ is obtained. According to equation (5)—

$$W' - C - w = W_0'$$

which is the constant normal displacement. Hence the intercepts between the curve $W' - C$ and the vertical line through the intersection between the W′ curve and $W_0 L_0$ must be equal to the water-ballast w, and the curve $W' - C$ must be congruent with the curve for w set off directly from the base.

The curve for W, the displacement of the always-buoyant volume, runs parallel with the $(W' - C)$ curve from the top down to the point where the tank begins to emerge above the water. Above this point the intercept between the two curves is everywhere w_2, the total amount of water-ballast. Below this point the intercept is $w_2 - X$. The curve for X is shown dotted; the intercept between it and the W curve is again w_2. The vertical dotted line representing W'_0 passes through the top point of the W curve, since $W'_0 = W_2$. In the calculation of i, the moment of inertia of the free surface in the tanks, it was necessary to assume a certain order in which the flooding took place. While I_2 is equal to zero, i_2 has a considerable value due to a free surface in ballast tanks other than the main tanks and in some of the oil tanks.

The curves for B, M, G, s, and t give the height of these points above the bottom of the keel, K. These curves are constructed as usual in metacentric diagrams by setting the respective heights up vertically from the horizontal base line through K along ordinates determined by transferring the draughts to a diagonal line drawn at 45 deg. to the base. The curve for the centre of gravity, G, is a straight line. The vertical intercepts between this line and the curve for M give the metacentric heights at all stages of immersion, and show clearly its minimum value and the point at which it occurs.

Remarks on Professor Hovgaard's Paper.

By Cesare Laurenti, Naval Architect, Member.

The interesting paper read by Professor Hovgaard, whose competence in the matter is acknowledged by everybody, brings into public discussion a question concerning submarines which till now was known only to designers.

Everything relating to submarines is always kept very secret, and that has prevented their rapid progress, as every designer and every builder kept his data secret, as also the trials with models in the Froude tanks, and therefore the technical knowledge of submarines has developed slowly. Professor Hovgaard has for a long time past been an exception, and we all must be grateful to him.

The question of stability during the diving period is often discussed between constructors and commanders of submarines; but the commanders are not very well acquainted with certain principles of naval architecture and cannot always interpret results of calculations; Professor Hovgaard's paper will therefore be highly appreciated by students of these problems.

I am perfectly in accord with Professor Hovgaard in saying that the period of submersion must be considered as a continuous one, without interruption, during which the free surfaces in the ballast-tanks, when they are on the sides of the ship and are divided by a watertight keelson, must be considered separately; so that the moments of inertia must be taken separately about the longitudinal neutral axis of the said free surface.

Care should be taken when in the diving condition, as the addition of water ballast reduces the initial metacentric height very rapidly; it reaches a minimum value when the free water surface in the ballast-tanks reaches a maximum. Great care should be taken, therefore, that a critical condition does not arise. But I hardly think that in a well-designed submarine it would be possible for the metacentric height to pass this critical point and reach a negative value, however much the vessel may be inclined.

The transverse inclinations which can be reached during immersion, and which assume the maximum values corresponding to the minimum values of the coefficient of resistance, are generally caused by slight transverse want of symmetry of the fixed weights. If the vessel takes, say, 1 deg., or little more, of lateral inclination on the surface (which is almost imperceptible), the inclination is considerably augmented when the resistance to inclination is reduced by three-quarters or more, and is assisted, moreover, by the greater introduction of water on the inclined side. Near the final period of immersion the ship is always upright. I also, as well as Professor Hovgaard, do not know of a single case of a submarine that has capsized from this cause.

Especially is this the case in the latest submersibles, where many weights, such as guns, ammunition, periscopes, &c., have been added after completion, in elevated positions, with the result that the coefficient of resistance to transverse inclination has been reduced from that of the original design, and it is not rare in such cases to have, during immersion, inclinations of about 10 deg. The diagram for the value of the initial metacentric stability during immersion that I have always prepared for commanders of submarines is a little different from Professor Hovgaard's diagram, but it is easier to follow, for it gives, corresponding to each external water-line, the external displacement of the ship, the weight of water in the main ballast-tanks, and the segments comprised between the two curves representing the metacentric height and the height of the centre of gravity from the base-line of the vessel, representing directly the initial metacentric height (see Fig. 6 on next page).

It is understood that the metacentric heights take into consideration the deductions due to the various free water surfaces in the ballast-tanks. By this method we soon find the condition of minimum coefficient of resistance. The various construction curves for the final diagram must be traced with much accuracy, particularly through the points where the profiles of the square sections of the boat are rapidly changing in form.

All constructors of submarines will agree with Professor Hovgaard that the main water-ballast tanks must be as short as possible and concentrated in the middle part of the boat. Nevertheless it is often necessary to put a portion of the water ballast, sometimes not a negligible amount, near the extremities of the ship; in this case these ballast-tanks must be constructed in such a way that they must fill more rapidly than the main ballast-tanks, so as to avoid longitudinal inclination at the last moment of the immersion.

I do not agree with Professor Hovgaard when he says that the main ballast-tanks should not be emptied by compressed air in cases of emergency; this is to be recommended only in the case in which the outer skin of the ballast-tanks is light; in other cases, where the hull is also strong in the outer skin, it is a common practice to fill it with high-pressure compressed air; of course the ballast-tanks must then be provided with special security valves. I have assisted on many occasions where this operation has been carried out in 90 ft. depth of water.

I do not agree with the opinion of Professor Hovgaard and other constructors of submarines upon the usefulness of the "emergency tank." In case of emergency the buoyancy necessary for a submerged boat must be obtained very rapidly; and the operation of emptying all the ballast with high-pressure compressed air is not so rapid as the circumstances in many cases require; in these cases nothing but a convenient weight, rapidly detachable from the boat, is efficient. I know that many drawbacks can be urged against the "drop-keel," but giving up the use of the drop-keel for the 2 per cent. of the displacement at the surface condition does not seem to me to be a convenient plan. We thus renounce a means of giving a submarine the chance of suddenly rising to the surface in case of emergency.

The German submersibles have an "emerging" tank, not for emergency, but for normally reaching the

surface, because they are obliged to empty the ballast with a fan, which takes air to send into the tanks from a tube in the back of the upper part of the turret.

The principal objection to the use of the drop-keel is the impossibility of diving again after the keel has been dropped, but this objection can be removed if arrangements are made for filling a tank of the same capacity as the weight of the drop-keel. I could tell of many cases in which boats have certainly been saved by the detachment of a drop-keel.

I see that Professor Hovgaard calls "auxiliary tanks" what are usually termed "compensating tanks," situated, as he correctly says, about the centre of the gravity of the boat. Instead of proportioning this capacity to the variation of density of the water, it is better that this capacity should derive from a direct calculation for each type of boat, according to the conditions to be fulfilled. I used to make two calculations: one, with the boat in light condition (after the maximum consumption of provisions, ammunition, stores, &c.) in water of high specific gravity, and another calculation with the boat in heavy condition (with provisions, stores, ammunition, &c., complete) in water of low specific gravity, and from a comparison of these two calculations the capacity of the compensating tank was obtained.

The actual tendency of the commanders of submarines in the present war is to abolish the "adjustment tank." In war, immersion is required to be made in the minimum time which is possible, and is now reached in less than one minute. The actual practice is to make not statical immersions but dynamical immersions, that is to say in motion, and the captain does not then know the real distribution of weights in his boat; in such a case he is forced to make, during the immersion, only an approximate compensation.

During the under-water navigation he sees, from the angles of his horizontal rudders, if his boat is light or heavy, and he has time to correct the amount of water in the compensating tank till the boat can run horizontally with the rudders in a horizontal position. During the correction of weights the equilibrium of the boat is maintained by external forces, created by the rudders and the resistance to propulsion.

In regard to the position of the oil tanks, I agree perfectly with Professor Hovgaard that the best position must be preferably high up in submersibles with double hull, but this only on account of stability. In the old German submersibles this was the position selected. From the naval point of view this is not a good arrangement, as the tanks in this position are exposed to damage by shells; they must, therefore, be placed in the highest position possible, but always under water-line. This is what I have done in my type of submersible, as has been noted by Professor Hovgaard.

It would be desirable that Professor Hovgaard should complete his interesting study by going into the problem of the stability of submarines navigating on the surface with water-ballast tanks open to the sea, but with air valves closed, and the stability of the same, during the period of immersion, with compressed air in the tanks when, the boat being still immersed, the ballast-tanks are half empty.

These conditions are a little different from those of the period of immersion, with the Kingston valves of the ballast-tanks open, and escape air valves also open. In the first case it is necessary to take into consideration the complex buoyancy of the water and a compressible fluid (air) which, in certain cases, can alter the calculations made.

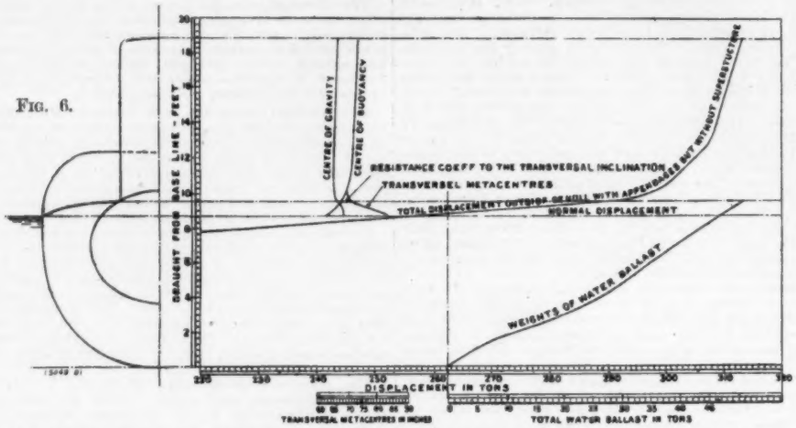
With a submersible of 700 tons surface displacement the area of the sea valves for filling the main ballast-tanks of the boat is about 1,800 sq. in. in the horizontal plane. If in this boat we begin to send compressed air into the main ballast-tanks for coming rapidly on the surface from a depth of 60 ft. (as very often happens when escaping from aeroplanes or submarine destroyers), then to the buoyancy corresponding to the Archimedean law must be added the pressure of the jet of water escaping from the valves under the influence of compressed air, a pressure of which we do not know the intensity, but it certainly attains some tons.

Another interesting case is that of the boat cruising on the surface with the Kingston valves of the main ballast-tanks open and the exhaust valves closed, an arrangement often adopted in submarines for reducing the time of immersion. In this case it is not clear if it is correct to consider the moment of inertia of the free water surfaces of the tanks about their neutral axis, as in the case of continuous diving, because the fixed displacement of the boat can force the two free surfaces of the water in the tanks to assume the same level.

I hope that all these investigations will soon be made by distinguished exponents of the science of naval architecture, for the guidance of constructors of submarines.

FIG. 6.

DOUBLE-HULL SUBMARINE STABILITY DURING IMMERSION


DRAUGHT FROM BASE LINE - FEET
CENTRE OF GRAVITY
CENTRE OF BUOYANCY
RESISTANCE COEFF TO THE TRANSVERSAL INCLINATION
TRANSVERSEL METACENTRES
TOTAL DISPLACEMENT OUTSIDE OR SOLL WITH APPENDAGES BUT WITHOUT SUPERSTRUCTURE
NORMAL DISPLACEMENT
WEIGHTS OF WATER BALLAST
DISPLACEMENT IN TONS
TRANSVERSAL METACENTRES IN INCHES
TOTAL WATER BALLAST IN TONS

NOTES FROM THE UNITED STATES.

PHILADELPHIA, March 21.

THE serious condition of recent development is the opening up of enormous Government requirements—largely naval—which must be attended to as soon as possible. This was foreseen a week ago, but it is clearer to-day. Last week the steel trade booked orders for nearly 1,000,000 tons of steel—the largest volume ever known in that time. Much of it was for new ships for the Navy—about one-fifth of the total. The other buyers were largely equipment manufacturers, tool workers and independent shipyards. Foreign munition orders have dropped off and will drop off farther. The market is, of course, overwhelmed with inquiries. Among these may be mentioned one for Europe for 200,000 tons of steel billets for shells. All steel plants are choked with business. Pittsburg and Youngstown are out of the market. Everything is moving up. The Bethlehem Steel Company is rushing to pick up whatever unsold steel plate capacity it can find. To enumerate all the steel plate inquiries now on the market from Atlantic, Lake and Pacific shipyards and Japanese yards would be a twice-told tale, and monotonous. Every maker of steel products from ships down wants steel for delivery six to eighteen months ahead. A 10,000 tons rail order is placed for Alaska roads. European interests are seeking to place large orders for cars in this country and Canada. Tank cars are wanted in large numbers. A British syndicate is reported to have purchased for three million dollars the Chester Shipbuilding Company's plant, situated at Chester, a suburb of Philadelphia. The yard will be very greatly expanded. It enjoys every possible advantage for cheap and rapid production.

NORWAY TIN-PLATE MARKET.—The American consular agent in Trondhjem, says *The Iron Trade Review*, Cleveland, Ohio, reports a considerable shortage of tin-plate throughout Northern Norway, and manufacturers of canned goods are experiencing some difficulty in obtaining sufficient supplies to keep their factories running. Previous to the war tin-plate was obtained from England, but shipments from this source now only come in small quantities. A good opportunity therefore exists for the introduction of American tin-plate. There are from 15 to 20 canning factories in the Trondhjem district alone; these factories obtain their tin-plate through Trondhjem import agents.

THE FARADAY SOCIETY.—A general discussion on "Osmotic Pressure" will be held on Tuesday, May 1, 1917, at 8 p.m., in the Rooms of the Chemical Society, Burlington House, W. Sir Oliver Lodge, F.R.S., will preside over the discussion, which will be opened by Professor Alfred W. Porter, F.R.S. Dr. F. Tinker will read a paper on "The Colloidal Membrane: Its Properties and its Function in the Osmotic System." Mr. W. R. Bousfield, F.R.S., will read a paper on "Osmotic Pressure in Relation to the Constitution of Water and the Hydrates of the Solute." The following have signified their intention of contributing to the discussion:—Professor H. E. Armstrong, F.R.S., the Earl of Berkeley, F.R.S., Professor A. Findlay, Professor J. C. Philip, Dr. G. Senter, Dr. S. A. Shorter and Mr. W. C. Dampier Whetham, F.R.S.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—While Government work continues to absorb practically the entire energy of the steel makers in the West of Scotland, little change in the ruling conditions falls to be recorded, although the pressure in every department may be said to intensify as day follows day. The pronounced activity which is thus entailed is causing a very severe strain, which can only be relieved when the extensions and improvements now being rapidly pushed forward are quite completed. Once these are all available it will again be possible for makers to produce greater quantities of material and lay up some stock, for as it is the demands of Government alone are quite able to absorb the present output. For mercantile steel also the demand is extensive. Export shipments are still being seriously curtailed, the only steel going out of the country being consignments to France and Italy, and when permits are granted for these the quotations continue to run on the lines indicated last week. Ship plates and high-tensile steel bars are in constant requisition.

Malleable Iron Trade.—Just as in all the other branches of mercantile industry work in the malleable iron trade continues to run at the highest possible pressure, makers having an unlimited supply of orders for both their iron and steel departments. Every mill is kept busily employed, producing an extraordinary output, the bulk of which is required on Government account, the demands of the ordinary mercantile consumer being held subsidiary. "Crown" bars for home delivery are steady at 13*l.* 15*s.* per ton, while for the export trade the price is fully 15*l.* per ton and upwards, at which rate profits would be very considerable were it possible to put a large volume of business through.

Scotch Pig-Iron Trade.—The demand for Scotch pig-iron continues as heavy as ever, the iron works absorbing immense quantities of forge quality and the steel works being equally insistent for extraordinary deliveries of hematite. Foundry grades, particularly No. 1, are exceedingly scarce, the market being totally bare of stock. This continuous demand, the bulk of it being consumed locally, is keeping the producers more than fully occupied, the entire output being as quickly disposed of as produced. Prices are firm and unchanged.

New Member of the Clyde Trust.—It was intimated at a meeting of the Trustees of the Clyde Navigation, held a few days ago, that Mr. W. Rowan Thomson, of Messrs. David Rowan and Co., marine engineers and boilermakers, Elliot-street, Glasgow, had been elected to fill the vacancy in the Trust caused by the death of Mr. James Gilchrist, of Messrs. Barclay, Curle and Co., Limited. The chairman, Sir Thomas Mason, referred in felicitous terms to Mr. Thomson's many associations with the Clyde Trust in the past, and congratulated him upon his future connection with this important body.

Tube Workers and Increased Wages.—Intimation has just been received by the Workers' Union and the Amalgamated Steel and Iron Workers, the representatives of the tube trade workers, from Messrs. Stewarts and Lloyds and the Scottish Tube Company, that with the consent and approval of the Ministry of Munitions they have arranged to apply the award of the Committee on Production of March 1, 1917, to the employees in their several works. This means an additional 5*s.* per week to every man in the works as from the first pay in April. Bailie Robert Climie and Mr. Owen Coyle represented the men in all the negotiations.

ITALIAN AWARDS TO BRITISH SCIENTISTS.—We are glad to announce that the Società Italiana delle Scienze, Rome, has awarded to Messrs. W. H. Bragg and W. L. Bragg, Leeds University, in recognition of their work, its gold medal, 1916, for physics.

THE LATE MR. HORACE SHORT.—We regret to have to record the death, which occurred on Friday, the 6th inst., at his residence in the Isle of Sheppey, of Mr. Horace Short, one of the pioneers of British aviation and a leading figure in the British aircraft industry. Mr. Horace Short, in the earliest days of flying, in 1908, started an aeroplane factory on the Aero Club's testing ground, at Leysdown, Isle of Sheppey, working in conjunction with his brothers, Eustace and Oswald Short. They built there a large number of experimental aeroplanes; one of these, driven by Mr. J. T. C. Moore-Brabazon and fitted with a Green engine, won the *Daily Mail's* 1,000*l.* prize for the first circular mile flown on an all-British machine. The three brothers moved, later, to Eastchurch, where they built the biplanes in which were taught the first four officers permitted by the Admiralty to learn to fly. There were also built the first aeroplanes having more than one engine and propeller apiece. It was, however, as a designer and constructor of seaplanes that Mr. Short did the greatest service to the nation. As early as 1912 Short seaplanes driven by 100-h.p. Gnome engines were making flights from seas which no other hydro-aeroplane would have faced. In 1913 Mr. Short introduced his large seaplane having folding wings, thus enabling such machines to be housed in a space no wider than their own floats and making it possible to carry seaplanes of large size on small ships. The great Short seaplanes, provided with Sunbeam engines of over 200 h.p., have done great work in the war areas, and for this, if for no other reason, the memory of Mr. Horace Short will live with that of others who have deserved well of their country. At the time of his death Mr. Short was only 44 years of age. Much of his recent work is still in hand and will be duly carried to completion by his brothers.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Hull Coal Traffic.—The traffic through the Humber port during the past month amounted to 251,514 tons, which is a decrease on the corresponding period of last year of 10,245 tons. The total for the first quarter of the current year is 800,844 tons, or a decline of 72,129 tons on the same three months of last year. There are no other items in the return, for the figures relating to the foreign exports and coastwise traffic are not now available.

South Yorkshire Coal Trade.—The interference of the holidays will doubtless tend to increase the difficulties of the suppliers, for although it is early yet to arrive at a rough estimate of the position, it is certain that Eastertide has again lost the dealers, depôts and collieries ground, in the efforts they had been making to overtake the numerous arrears and also to allow works to build up something like substantial reserves. Most of the pits have been closed for two or three days, but there was not the general resumption yesterday that had been so confidently anticipated. Supplies are only small for the abnormal demand prevailing, as the majority of the works have already got into full running order again and are requiring the total amounts under their contracts. House coal users have again had to suffer to make up the deficiency, and there is now a distinct shortage of this class of fuel available for the legitimate customers. Larger steam sorts are only a moderate supply, whilst there are not enough nuts and cobbles to go round. Slacks are tight, and cokes at top values. Quotations:—Best branch hand-picked, 20*s.* 6*d.* to 21*s.* 6*d.*; Barnsley best Silkstone, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire best brights, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire house coal, 17*s.* to 18*s.*; best large nuts, 16*s.* 6*d.* to 17*s.* 6*d.*; small nuts, 15*s.* 6*d.* to 16*s.* 6*d.*; Yorkshire hards, 16*s.* 6*d.* to 17*s.* 6*d.*; Derbyshire hards, 16*s.* to 17*s.*; best slacks, 12*s.* to 13*s.*; seconds, 10*s.* 6*d.* to 11*s.* 6*d.*; smalls, 7*s.* 6*d.* to 8*s.* 6*d.* per ton at the pit.

Iron and Steel.—The reports to hand indicate that a splendid start has been made after the holiday, which in the large number of cases extended to three days. The interval was a welcome break after a long spell, and both masters and men are confident good will accrue. Some of the workers have undoubtedly been getting shop-sick, and the rest has been most opportune. Plant has benefited by the carrying-out of urgent repairs and by the general system of overhauling which has been put into practice. The week is but in its infancy when there comes a very heavy demand for all classes of common iron, itself an indication of the way in which all are bending themselves to the common task. There is some talk that in view of the present abnormal circumstances, coupled with a greater cost of production, an increase in the official maxima of prices would be granted if a strong case were made out, but makers would be sure to have strenuous opposition from the users, who find it difficult enough with present charges to work at that economy of production which the Ministry of Munitions desire. With the progress of the war the call for steel is growing amazingly, and both home and foreign requirements are on a very large scale. There seems to be little chance of the steel makers catching up with the demand, though they are being assisted in the home section by the policy of prohibition of certain overseas trade. High-speed carbon steel makers are now being reluctantly compelled to break off active overseas relations for the remainder of the war. Many of the firms have done little in the export of high-speed tools for some time, and now they are finding the same applies to the other class. Agricultural engineers still declare there is a ready market for all they can supply, but that they are in no sense catching up with the demand. Sheffield silversmiths have made some progress in stopping the total destruction of their trade for the want of raw material. Arrangements are being come to with the Government for the release of certain commandeered metals.

CAMMELL LAIRD AND COMPANY, LIMITED.—The report of the directors for the year ended December 31, 1916, states that the past year's trading has resulted in a profit of 321,372*l.* 2*s.* 11*d.*, which is an increase of 17,530*l.* 15*s.* 9*d.* over the profit for the preceding year. The works of the company have continued to be fully employed throughout the past year, and the output results have been eminently satisfactory. The directors propose a dividend of 10 per cent. on the ordinary share capital, to appropriate to reserve account 100,000*l.*, and to carry forward 94,494*l.* 6*s.* 1*d.*

THE ARMING OF JAPANESE SHIPS.—We are glad to note, says *The London and China Telegraph*, that the directors of the Nippon Yusen Kaisha have overcome their scruples with regard to the arming of their steamers as a protection against German submarine attacks. There can be no question that they have taken the right course, and in view of all that has happened the only surprise was that they should ever have had any hesitation on the subject. The day is past for any punctilious feelings sb far as Germany is concerned, such as were indicated by the directors when they first announced their intention to run their vessels without guns. Japanese steamers have been attacked and sunk without warning, but armed as they will be in future with two guns on each vessel, the sinking may not be all on one side. The weekly statistics issued by the Government show that a very large percentage of armed merchantmen attacked by enemy submarines make their escape. At any rate, they were in a far better position to resist the sea pirates than if they had no guns at all.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Holidays have this week interfered with business, but the market keeps very strong, though as yet export quotations of Cleveland pig have not followed last week's rise of 5*s.* for home consumption. Some traders opine that an upward movement in export prices is imminent, but others do not take that view. With iron fairly plentiful, and producers prepared to entertain extensive business, ample opportunity is afforded for making arrangements for forward supplies, subject to any official changes in prices, but few buyers appear desirous to avail themselves of the situation, and show little inclination to purchase ahead, preferring to give orders for early needs only. Allocations for April are now reported heavy. For home consumption No. 3 Cleveland pig, No. 4 foundry and No. 4 forge are all 92*s.* 6*d.*, and No. 1 is 96*s.* 6*d.*; whilst for shipment to our Allies No. 3 is 97*s.* 6*d.* and upward and No. 1 is 102*s.* 6*d.* and upward. The stock of Cleveland pig in the public warrant stores still stands at 2,147 tons, composed of 2,111 tons of No. 3 and 36 tons of other kinds of iron deliverable as standard.

Hematite Iron.—Great firmness characterises the hematite branch of the staple industry. Up to the present actual advances have not been made, but a pronounced and growing feeling prevails that the position fully justifies substantial rises. Home customers continue to receive ample supplies with a fair amount of regularity, the wagon situation having improved, and rather considerable quantities are available for shipment abroad, but export licences are still issued sparingly and with much caution, and those that are being secured are mostly for cargoes that should have already been despatched. Nos. 1, 2 and 3 were 122*s.* 6*d.* for home use, 137*s.* 6*d.* for shipment to France, and 142*s.* 6*d.* for export to Italy, but as sellers were mostly disinclined to entertain offers on these terms, quotations were very largely nominal.

Blast-furnacemen's Wages.—The average net selling price of No. 3 Cleveland pig-iron has just been certified at 89*s.* 8.76*d.* per ton for the first quarter of the year, as compared with 89*s.* 0.17*d.* per ton for the previous three months—a rise of slightly over 8¼*d.* This means an advance in blast-furnacemen's wages of 0.75 (¾ of 1) per cent., and raises wages from 71.25 per cent. above the standard to 72 per cent. above the standard.

Coke.—Demand for coke continues good both for home use and for shipment, and values are well upheld. Local consumption is heavy, and average blast-furnace kinds command the fixed maximum of 28*s.* at the ovens; whilst the limitation price of 30*s.* 6*d.* at the ovens is still named for qualities low in phosphorus.

Manufactured Iron and Steel.—Producers of finished iron and steel still steadily add to their huge output, the marked gradual growth of mercantile shipbuilding material being very gratifying. To home consumers common iron bars are, 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; best best bars, 14*l.* 10*s.*; iron ship plates, 13*l.* 10*s.* to 14*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; iron ship rivets, 17*l.* 10*s.* to 18*l.* 10*s.*; packing iron and steel (parallel), 13*l.* 5*s.*; packing iron and steel (tapered), 15*l.*; steel bars (no test), 14*l.* 10*s.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel ship rivets, 19*l.* to 20*l.*; steel boiler plates, 12*l.* 10*s.*; steel joists, 11*l.* 2*s.* 6*d.*; steel strip, 17*l.*; steel hoops, 17*l.* 10*s.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.*

Manufactured Ironworkers' Wages.—The accountants to the Board of Conciliation and Arbitration for the Manufactured Iron and Steel Trades of the North of England have certified the average net selling price of iron rails, plates, bars and angles for the two months ended February 28 last at 13*l.* 7*s.* 10.61*d.*, as compared with 13*l.* 5*s.* 7.22*d.* for the previous two months, and in accordance with the sliding-scale arrangements this carries an advance of 3*d.* per ton on puddling and 2½ per cent. on all other forge and mill wages.

STEEL WORKS EXTENSIONS IN NORWAY.—According to *The Anglo-Norwegian Trade Journal* the Stavanger Electro-Staalverk is increasing its capital to 4,000,000 kroner to provide for running the works by electricity, for which purpose the Ryfylke waterfalls have been leased. These are now being harnessed to produce about 7,000 h.p. It is also the intention of the company to extend its steel works, largely to increase the present capacity, and to erect rolling mills, the principal sections to be rolled being ship and boiler plates.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—At the fourth annual general meeting of the Institution of Petroleum Technologists, the elections were announced of Mr. Charles Greenway as President, Professor John Cadman as a Vice-President, and of Sir Frederick Black, C.B., and Major A. Cooper-Key, C.B., as honorary members. The vice-presidents and council for the ensuing year are: Vice-Presidents: The Right Hon. Viscount Cowdray of Cowdray, Sir Thomas H. Holland, K.C.I.E., D.Sc., F.R.S., and Sir Boverton Redwood, Bart., D.Sc., F.R.S.E. Council: Alfred C. Adams, Herbert Allen, Sir Robert Balfour, Bart., M.P., Captain R. W. Barnett, M.P., Herbert Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A., Sir George Beilby, LL.D., F.R.S., Edwin R. Blundstone, B.A., F.C.S., Andrew Campbell, John T. Cargill, E. H. Cunningham Craig, B.A., F.R.S.E., F.G.S., Arthur W. Eastlake, M.Inst.M.E., A.M.I.Mech.E., T. C. Palmer, Assoc.M.Inst.C.E., F. Mollwo Perkin, Ph.D., F.I.C., F.C.S., and Robert Redwood, F.C.S.

NOTES FROM THE SOUTH-WEST.

Cardiff.—Business was practically suspended over the holidays from Thursday of last week until Wednesday of this week, when there was a considerable improvement in the attendance on 'Change. Although very little new business was even then transacted, the undertone was quite steady. The returns from the collieries showed that the great majority of the workmen had returned, and that the percentage of absenteeism was much below the normal for a holiday week. It was stated that in many cases 85 to 90 per cent. of the men had resumed work on Wednesday, and that only in rare cases was the percentage of absenteeism over 20 per cent. In several parts of the coalfield, however, there has been a very heavy downfall of snow, and this has handicapped traffic, and to some extent reacted on production. There was a fair supply of tonnage at the Cardiff docks. At both Cardiff and Penarth practically all tips were in use, while at Barry two or three steamers were waiting berths. Prices nominally are unchanged, but they are firmly quoted round about 24*s.* for second Admiralty descriptions, and between 12*s.* and 14*s.* for ordinary smalls.

Increased Freights to Neutrals.—What created more stir than anything else during the past week was the posting up of the following notice on the Exchange by the Local Limitation Committee:—"Coal exporters and brokers are hereby informed that the rates for neutral steamers have been advanced as follows: (1) East and West Coast of Great Britain to North French ports not south of Brest by 12*s.* per ton, making the freight the schedule rates plus 50 per cent. and an additional 12*s.* (2) East and West Coast of Great Britain to Bay ports south of Brest by 18*s.* per ton, making the freight the schedule rates plus 50 per cent. and an additional 18*s.* Kindly note that the above figures are not to affect chartered freights of vessels covered under the old war insurance previously to April 9." It will be noted that this revision on the freight rates for neutral steamers is limited to the French ports and Bay coast. It is understood that the raising of the rates for neutrals in respect of the Mediterranean is also under consideration. This makes the fourth alteration in the schedule rates during the past three or four months.

THE MARINE SERVICE REVIEW AND R.N.R. GAZETTE.—There was issued this month the first number of a monthly magazine having this title, and edited by Mr. D. H. Burnand, Master of Marine. The introductory editorial article states that the primary objects are "to foster and further the interests of our great merchant service, having regard to the vital part it has played in this war, and the additional status it has attained, particularly in relation to the Navy; and to infuse *esprit de corps* between professional seafarers and those connected with the great shipping industry ashore." The price is 6*d.*, and it is published at 5, Richmond-street, Liverpool.

OPENING IN GERMANY FOR NON-FERROUS METALS.—We read in *The London and China Telegraph* that a letter written by a Hamburg firm to branches in Japan, which was read in the Prize Court, said:—"We request you to inform us if you will be able to supply us with large quantities of very heavy copper and bronze vases, also animals. We lay no importance on their execution or shape; you can send us the roughest and most faulty examples. The animals must be massive, and not hollow, and must have the appearance of curiosities. If you can ship 10 to 20 tons per month direct to Sweden as curiosities . . . we shall be glad if you could arrange to pack the cases with raw rubber so that the works of art should not suffer. Aluminium objects also have considerable interest for us."

THE INSTITUTION OF SHIPBUILDERS AND ENGINEERS IN SCOTLAND.—There has just been issued from the offices of the Institution, 39, Elmbank-crescent, Glasgow, the "Transactions" for the fifty-ninth session of the Institution, and the volume has a corresponding number. The "Transactions" contain papers and discussions on a variety of subjects, including alternative types of propelling machinery, a new method of bending plates for eliminating riveted joints in light steel boat construction, the manufacture of Portland cement, a suction-gas producer using bituminous coal, the decay of metals, the Ljungström marine turbine, and ball bearings. As the papers are well illustrated the volume should be acceptable to all interested in shipbuilding and engineering. It is edited by the secretary, Mr. Edward H. Parker.

COKE OVEN BY-PRODUCTS IN THE UNITED STATES.—Our American contemporary, *The Iron Trade Review*, notes with satisfaction that the United States iron and steel industry has been vigorously carrying forward of recent years the construction of coke plants of the by-product recovery type. It is estimated that the country is to-day producing pure or refined benzol at the annual rate of 30,000,000 gallons; pure toluol from 6,000,000 gallons to 8,000,000 gallons; and phenol from 25,000,000 lb. to 30,000,000 lb. In the midsummer of 1914 the American annual production of pure benzol was at the rate of 3,000,000 gallons; of toluol 750,000 gallons; and of phenol 120,000 lb. In 1916 the country produced about 325,000 tons of sulphate of ammonia equivalent, compared with 183,000 tons in 1914. After the war much of the coal-tar products now going in some form to European battlefields will be diverted to peaceful purposes. Furthermore, adds our contemporary, the American manufacturing efficiency will have been greatly promoted by the advantages which the by-product method of coke-making possesses over the bee-hive process.

AMERICAN INSTALLATIONS FOR COALING LOCOMOTIVES.

(*For Description, see Page* 345.)

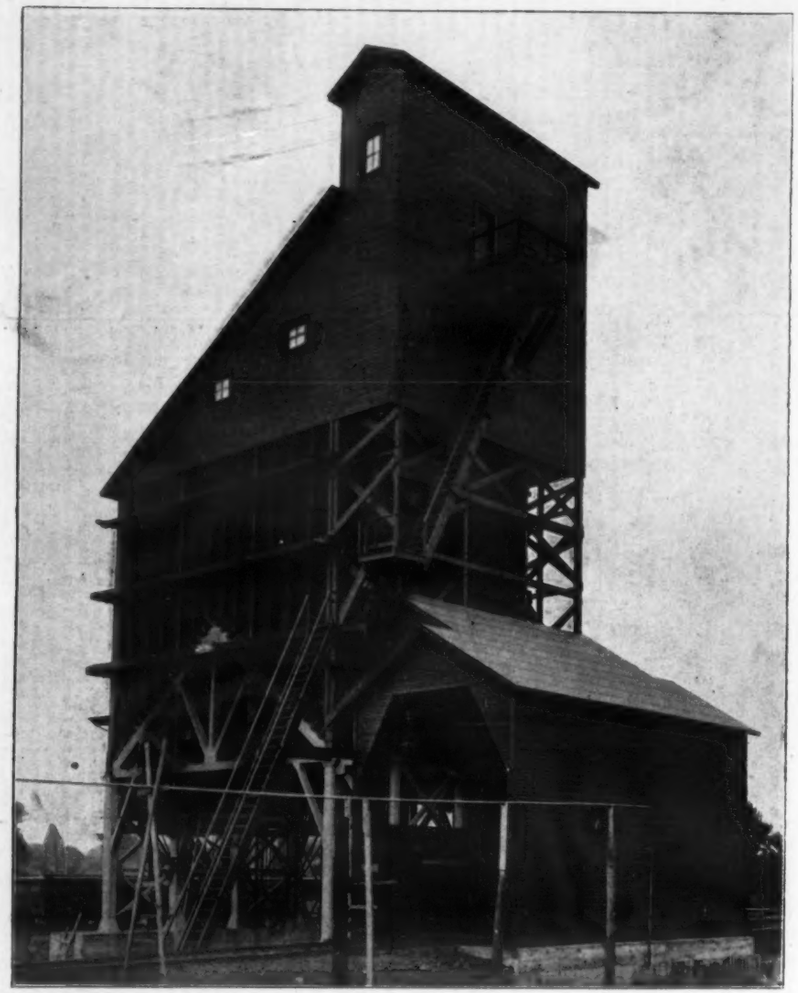


FIG. 14. COALING STATION AT GREENSBURY.

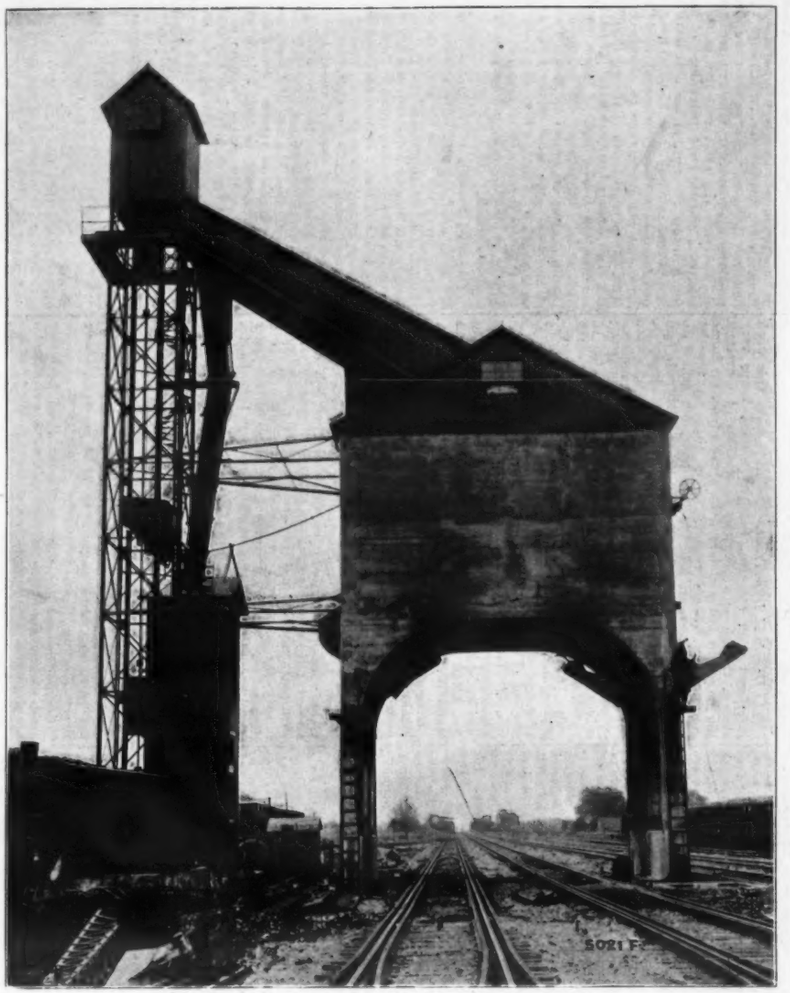


FIG. 15. COALING STATION AT COWAN, TENNESSEE.

RESIN AND TURPENTINE IN GERMANY.—Resin and turpentine, the former of which has been used to the extent of 80,000 tons per annum, are now becoming exceedingly short in Germany, and the necessity of obtaining further supplies has directed attention to the hitherto unutilised resources of their own pine and fir forests. The former have already been ransacked and the resin scraped off the trees, and in some localities pine forests have yielded as much as 80 lbs. per acre, but this appears to have been an exceptionally favourable figure. In order to obtain further quantities of resin the fir forests are now being overhauled; these should give rather better results, and there are 14,000,000 acres of such forests available in Germany, which resources are estimated to be sufficient to yield the required amount of resin, but only about half the quantity of turpentine consumed annually. To procure the latter it is intended to use fir-scrub; this is treated with a lye of caustic soda at a temperature of 170 deg. while under pressure. It is stated that in the Prussian State forests alone there are over 137,000 cubic yards of fir-scrub which can be used for this purpose, and it is estimated that they will yield 3,100 tons of resin, 1,500 tons of turpentine, and 13,500 tons of cellulose.

AMERICAN INSTALLATIONS FOR COALING LOCOMOTIVES.

(For Description, see Page 345.)

Fig. 1.

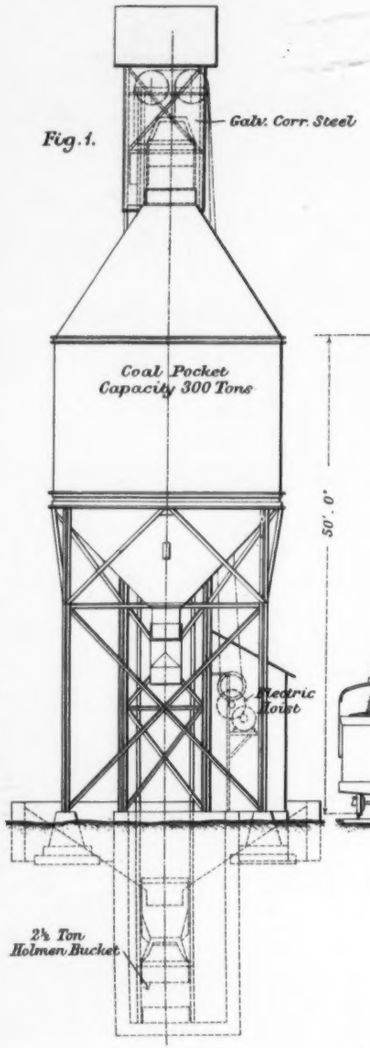


Fig. 2.

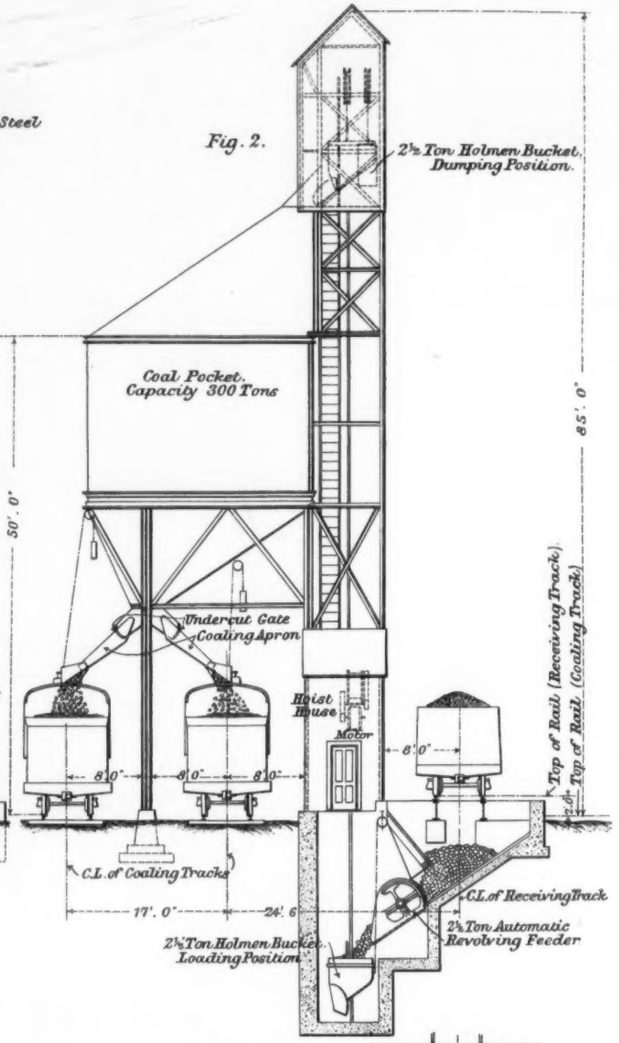
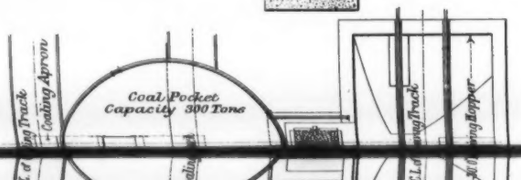
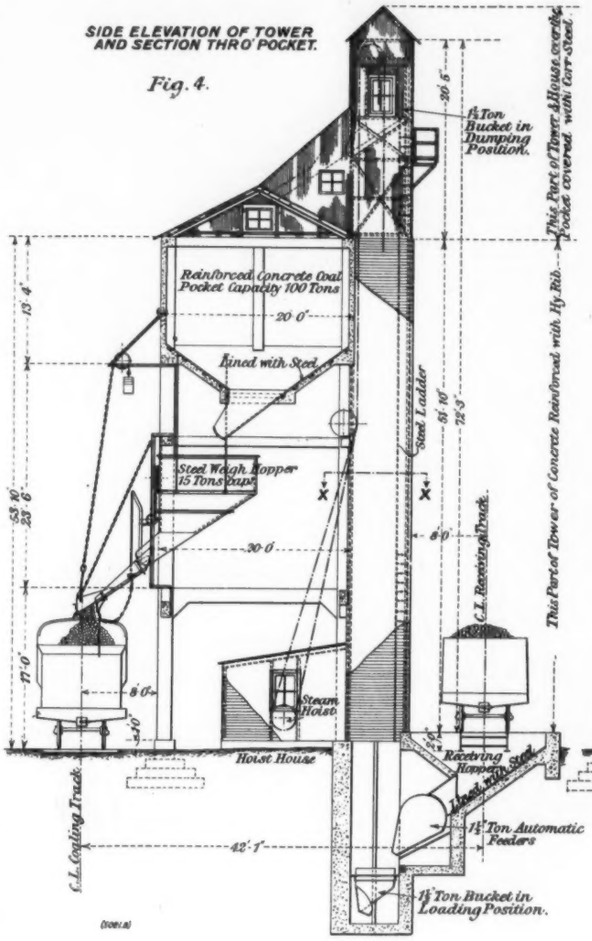


Fig. 3.



SIDE ELEVATION OF TOWER AND SECTION THRO' POCKET.

Fig. 4.



ELEVATION LOOKING FROM RECEIVING TRACK

Fig. 5.

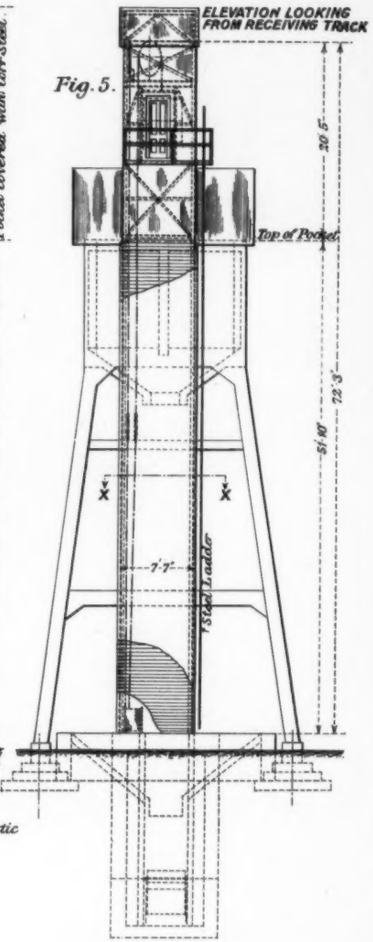


Fig. 6. SECTION X.X.

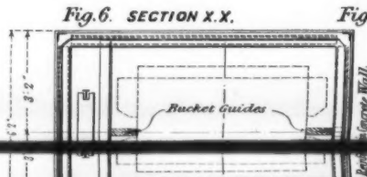


Fig. 7. PLAN OF CORNER OF TOWER.

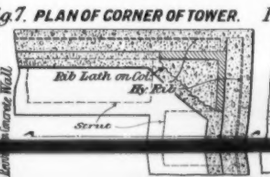
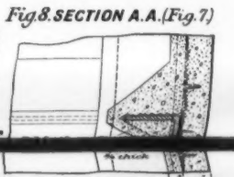
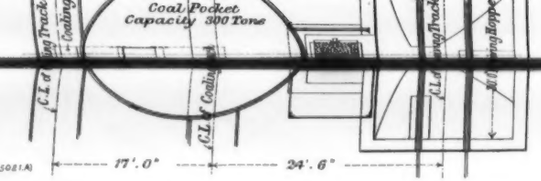
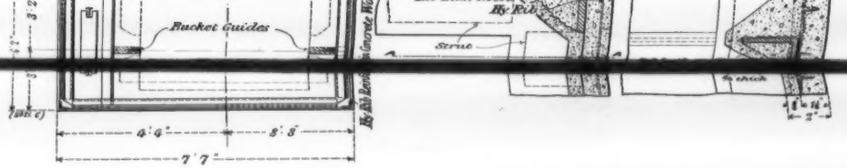


Fig. 8. SECTION A.A. (Fig. 7.)





FIGS. 1 TO 3. 300-TON HOLMEN COALING STATION AT WAUKEGAN, ILLINOIS.



FIGS. 4 TO 8. 100-TON REINFORCED CONCRETE COALING STATION AT CHIHUAHUA; NATIONAL RAILWAY OF MEXICO-PAREDON, MEXICO.

Fig. 9.

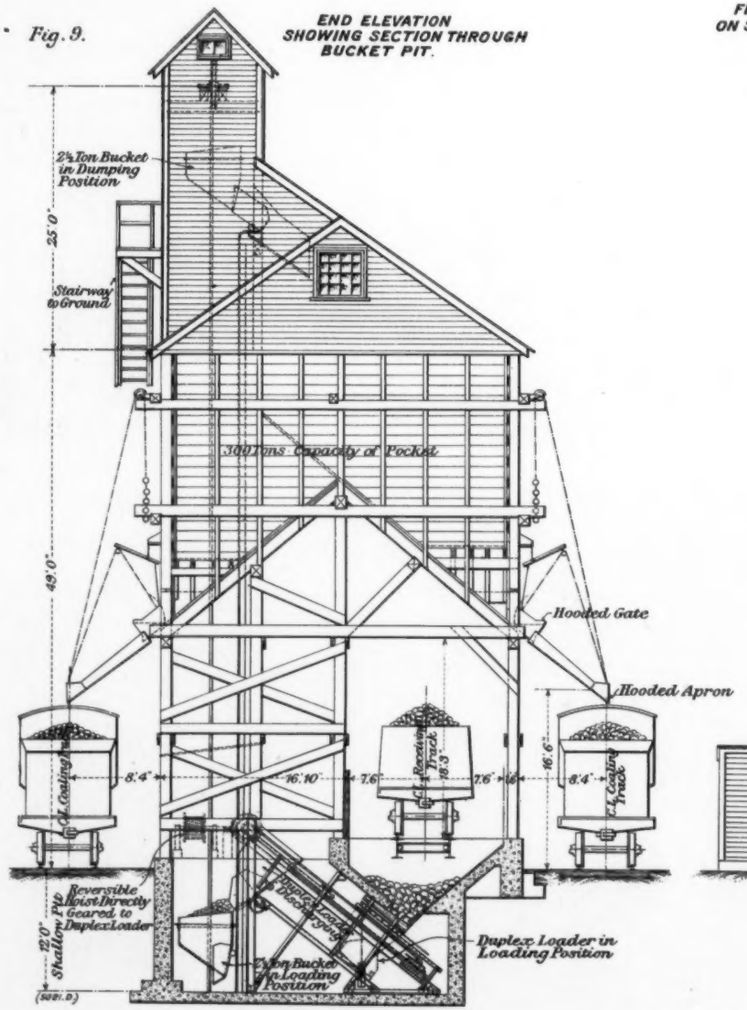


Fig. 10.

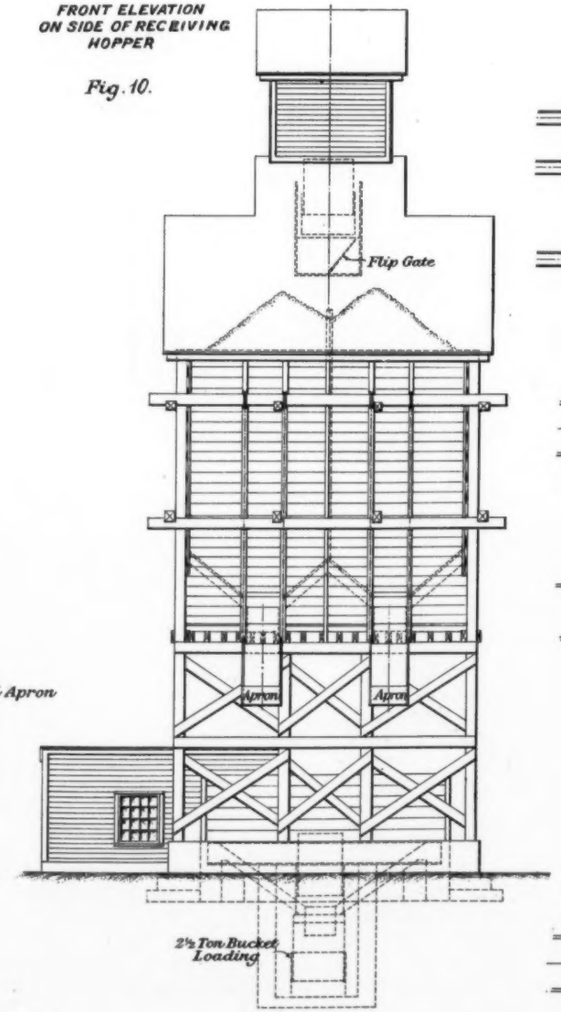


Fig. 11.

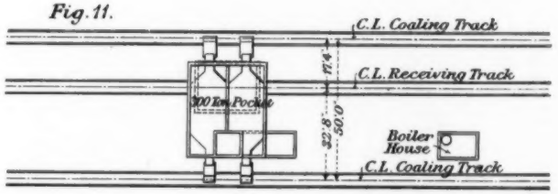
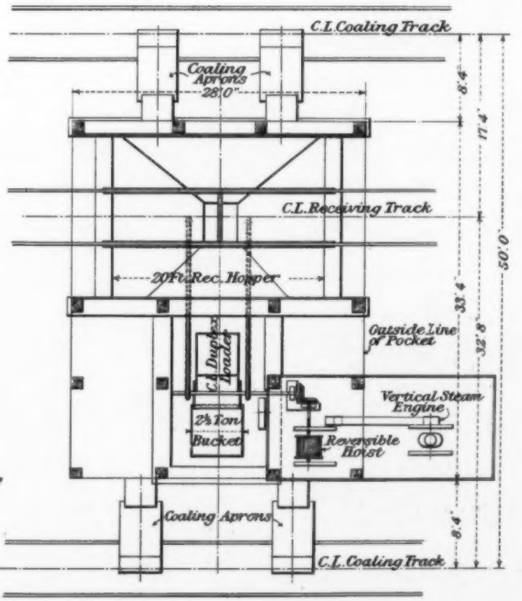


Fig. 12.



FIGS. 9 TO 12. 300-TON STANDARD BALANCED BUCKET COALING PLANT AT PAINTSVILLE, KENTUCKY; CHESAPEAKE AND OHIO RAILWAY.

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ADVERTISEMENT RATES.

The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

SUBSCRIPTIONS, HOME AND FOREIGN.

REVISED RATES.

"ENGINEERING" may be ordered from any Newsagent in town or country and at railway book-stalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

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Thin paper copies	£2	0	6
Thick "	£2	5	0
For all other places abroad—			
Thin paper copies	£2	5	0
Thick "	£2	9	6

When foreign subscriptions are sent by Post-Office Orders advice should be sent to the Publisher.

Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford-street, Strand, W.C. 2.

Offices for Publication and Advertisements, 35 and 36, Bedford-street, Strand, London, W.C. 2.

We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3063 and 8586 GERRARD.

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With a Two-Page Plate of AMERICAN INSTALLATIONS FOR COALING LOCOMOTIVES.

NOTICES OF MEETINGS.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.—Saturday, April 14, at 2 p.m., in the Wood Memorial Hall, Newcastle-upon-Tyne. The following papers will be open for discussion:—"The Economical Production and Utilisation of Power at Collieries," by Mr. F. F. Mairet. "Further Notes on Safety Lamps," by Mr. Simon Tate. The following papers will be read or taken as read:—"Some Practical Notes on the Use of Timber in Coal Mines," by Mr. F. C. Lee, M.A. (Chin.), B.Sc. "The Horsley and Nicholson Automatic Compound Syphon," by Mr. George R. Nicholson, F.I.I.

THE CERAMIC SOCIETY.—Saturday, April 14, at 7 p.m., at the Central Schools of Science and Technology. A paper will be read by Mr. S. T. Wilson, entitled "The Firing of Pottery Ovens."

THE SURVEYORS' INSTITUTION.—Monday, April 16, at 5 p.m. A paper on "The Effect of War Conditions on Urban Property" will be read by Mr. J. G. Head, Fellow.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, April 17, at 5.30 p.m. Annual general meeting of corporate members only, to receive the report of the Council, and to elect the Council and auditors for the ensuing year.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, April 17, at 8 p.m., at the House of the Royal Society of Arts, John Street, Adelphi, W.C. 2. The following paper will be read:—"The Development of the Petroleum Industry in Assam," by Mr. H. S. Maclean Jack. The chair will be taken by the President, Mr. Charles Greenway.

THE ASSOCIATION OF SUPERVISING ELECTRICIANS.—Tuesday, April 17, at 7.15 p.m., at St. Bride's Institute, Bride Lane, E.C. A paper will be read on "The Wiring Rules of the Institution of Electrical Engineers," by Mr. W. R. Rawlings, M.I.E.E.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, April 18, at 5 p.m., at 70, Victoria Street, Westminster. Papers to be read:—"The Diurnal Variation of Atmospheric Pressure at Benson, Oxon, during 1915," by Mr. E. G. Bilham, B.Sc., F.R.Met.Soc. "Atmospheric Electrical Phenomena during Rain," by Lieut. C. D. Stewart, R.E., F.R.Met.Soc.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS, LONDON, INCORPORATED.—Wednesday, April 18, at 7 p.m., at Caxton Hall, Westminster. Paper by Mr. R. P. C. Sanderson, Vice-President, and European representative of the Baldwin Locomotive Works, on "The Use of Steel in Fire-Boxes of Locomotive Engines."

THE INSTITUTION OF MINING AND METALLURGY.—Thursday, April 19, at 5.30 p.m., at the Rooms of the Geological Society, Burlington House, Piccadilly, W. The twenty-sixth annual general meeting. At the conclusion of the business of the general meeting the following papers will be submitted for discussion:—"Stope Measurement at Messina," by Mr. William Whyte, Associate. "Platinum in Spain," by Mr. F. Gilliman, Member.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.—Thursday, April 19, at the University, Edmund Street, Birmingham, Professor W. J. Ashley, of the University, Birmingham, will read a paper on "The German Steel Syndicate and the British Steel Industry." Chair to be taken at 6.30 p.m.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, April 20, at 6 p.m., at the Institution of Civil Engineers, Great George Street, Westminster. The President, Mr. Michael Longridge, will deliver his address.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, April 20, at 5.30 p.m. A discourse will be delivered by Professor R. H. Biffen, M.A., F.R.S. The subject is "The Future of Wheat-Growing in England." Afternoon lectures next week at 3 p.m. Tuesday, April 17. Professor C. R. Beazley, D.Litt., on "Russian Development—the Old Free Russia" (Lecture I). Thursday, April 19. Professor H. S. Foxwell, M.A., F.B.A., on "Industrial Finance after the War—the Character of the Industrial Struggle of To-Day" (Lecture I). Saturday, April 21. Professor G. H. Bryan, Sc.D., F.R.S., on "Principles of Aerial Navigation" (Lecture I).

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal from 6d. to 8d. per copy. This increase dated from and included the issue of Friday, March 16. The change will not apply to unexpired subscriptions.

DEATH.

EDWARD HAYES, M.Inst.C.E., M.I.Mech.E., at Mansfield, Stony Stratford, Bucks, on April 5, aged 72.

ENGINEERING.

FRIDAY, APRIL 13, 1917.

THE INDISPENSABLE MAN.

THERE are many things which can only be replaced or renewed at the cost of very great disturbance. In a utilitarian aspect they are indispensable, because their replacement demands both trouble and expense, and may not be complete. The term indispensable is, however, relative, since we may assume that the principal activities of Nature suffered no change by man's advent into the world, and will persist after his departure. It is difficult, no doubt, to visualise the prehistoric world, or the aftermath in the contingency of man's total disappearance. Yet the fact remains that but for the accident of a film of atmosphere and reasonable temperature (a few degrees either way would be enough to render life impossible) man could not have existed at all. "I should hesitate to describe any man as indispensable, but his value is such that considerable inconvenience, delay, and disturbance, would be caused by his removal." In such terms the chief of an essential service appealed for one of his principal assistants. Some men are pivotal, the majority can with small trouble be replaced, hence the famous dictum of Carlyle. No single man's death is going to stop the hands of the clock, although there exist individuals who labour under such delusions.

In spite of this, to withdraw the pivot means dismantling the mechanism and making inert material, if not scrap-iron, of a complex and laboriously constructed machine. The hinge-pin may be a passive member, supplying no power, but it is essential all the same. One man is as good as another is a frequent assumption, and intrinsically, for certain purposes, there is truth in the statement. Yet who can contemplate with indifference the withdrawal of more than one pivotal man in any organisation at the same time. The business may and possibly will survive, but the readjustment necessary means virtual reconstruction. Not that it is by any means certain that the best-paid are thereby indicated—recent events seem to show otherwise.

Large numbers of otherwise intelligent people lack the essentials which place them in the category indicated. They refuse to *make* themselves pivotal, a quality which in one respect at least depends upon independent thought. Few people do their own thinking, and thereby need detailed direction and guidance—the man finding the latter is the pivotal man. The chief function of a pivot is that other masses revolve round it as centre; such motion involves wear, and above all else it needs good and durable material. For this reason in a human sense one man is decidedly not as good as another.

There are many large businesses where no member of the board of directors is pivotal; *the* man is an employee, and he may not even be the manager. In fact it is obvious that where a considerable firm survives there must be first-class human material somewhere in its composition, but in some instances it takes quite a search to unearth it. Once the essential man is discovered further troubles are minimised. It is one of the unrecorded assets of a good commercial traveller that he can spot the right man, wasting no time upon anyone else. A play staged in London some years ago emphasised this idea. The hero was a butler who was cast ashore with the family he served on an uninhabited island. Instinctively and without question the servant was deferred to in the time of crisis, because it was realised he was, under the circumstances, the essential man. There was nothing in the way of position or possessions to hamper free development of native ability. When the castaways were rescued and returned to civilisation the butler became the servant again. The point at issue (and the present contention) is that the butler was a pivotal man round whom events revolved without creaking, who had initiative and resource, and instantaneously became the centre of affairs.

Where the nominal force is the real executive, where in reality the titular chiefs are the essential men, there organisation and system succeed and business prospers. The amazing progress of some concerns is inexplicable on any basis of favour, influence or circumstances, the success is due because their nominal pivots are pivotal men round which the business revolves.

One of the drawbacks to bureaucracy is that the development of pivotal ability is hampered by the incidence of its selection and system. It may happen that a man of the type indicated gets the hinge-pin job, but the odds are greatly against such a happening. Hence the well-founded complaints that such systems only swing erratically, they do not revolve save with protestation, and if compelled to move do so with lamentation. The choice of a man with latent ability (always difficult to assess) and the placing him in a position affording scope for development is more than half-way to success in large organisation.

Individual ambition is by no means a qualification; it is often the least equipped who are certain

of their powers, and the more reticent who succeed, given encouragement. Ability in itself is also not the essential qualification; to be erratic is a privilege of genius, and the tragedy of brilliance lacking stability is only too frequent.

The basic essential for indispensability is character. There must be ability, ambition and brilliance, but the dominant note must be character. It is the quality of the material which is essential, and human quality is measured by character. Copy-book platitudes are not meant, nor moral precepts, though since common-sense approves their sanity character includes them. Generosity of spirit, definite and specific ability, judgment, co-ordination, vision and experience are among the qualities meant; yet although recognition of character is easy, analysis of its components is difficult. Since a pivot must be lubricated, there is the oil of human kindness and tolerance to serve this end, otherwise tact and discrimination.

To cultivate the right attitude demands peculiar virtues, to achieve distinction in the school of character results in finely wrought and tempered material. The pivotal man has an inherent capacity for readjustment that inferior minds imitate by mimicry. Every quality having drawbacks, it is not easy for the type of man indicated to allow for direct stupidity, and he rarely suffers fools gladly.

The issue of impossible commands is sure evidence of a lack of pivotal ability; the means must be possible or the command is vain. The man of character in a pivotal position is the indispensable man, whether for the sake of argument he be store-keeper, designer, manager or simple foreman. He *may*, for that matter, even be a director; the point is that he must be pivotal or he hampers the machine if located in a responsible capacity.

RECENT DEVELOPMENTS OF MOLECULAR PHYSICS.

WHEN Lord Kelvin delivered his last Royal Institution discourse on April 27, 1900, his subject was: "Nineteenth Century Clouds on the Dynamical Theory of Heat and Light." Two new theories have since been advanced to disperse these clouds, revolutionary conceptions, not generally accepted, but commanding the serious attention of all mathematical physicists. To review these "Recent Developments in Molecular Physics" was the object of the discourse given on the 30th ult., at the Royal Institution, by Professor J. H. Jeans, F.R.S., of Cambridge, for some years at Princeton University, New Jersey, now residing in London.

The first cloud with which Professor Jeans dealt concerned the theory and aberration of light. The astronomer knew, he said, that he did not really point his telescope at the star he was observing; the man in the street was not holding his umbrella in the direction of the falling raindrops. The astronomer could watch the relative change in the position of a star in the course of years. In making his estimates he had to compound the velocity of light with the velocity of the earth. The earth might be supposed to sweep through the æther—there was another possible assumption—overtaking the ripples or light waves coming on and leaving them behind afterwards. It was somewhat the case of the man in the boat; going up-stream he overtook more ripples than going down-stream, and counting the ripples either way, he might arrive at an estimate of the rate of the river current. Similarly it ought apparently to be possible to estimate the æther drift past the earth from the difference in the velocity of light measured first in the direction of the motion of the earth and then in the opposite direction. All the various experiments made had, however, failed to disclose the existence of any such difference; thus it was concluded, either that the æther had no velocity relative to the earth, or that we were unable to detect it. The theory proposed to disperse this cloud overshadowing the dynamical theory of light, viz., the theory of relativity, started from the supposition that science had no means of deciding whether the æther was at rest or in motion, since we can only measure relative motion. That theory, therefore, took away the function of the æther, and it did not matter whether the æther existed or not—a point to which the lecturer reverted. It might be objected, Professor Jeans continued, that the removal of that cloud only brought up others. But the relativity theory actually cleared up other difficulties. Einstein had recently extended the relativity theory to comprise the laws of gravitation, which stood apart from all other laws, as unexplained, and it resulted that the law of inverse squares was only a first approximation. Professor Jeans alluded only to one exemplification in this connection, the case of the planetary orbits. The planets did not merely move in ellipses, but those ellipses seemed to rotate in the direction of the movement; Einstein had calculated that, in the case of Mercury, the nodes should move by 42.9 seconds of arc per century; the observed, but hitherto unexplained, value of astronomers was 43 seconds.*

The second cloud, Professor Jeans proceeded, concerned the dynamical theory of heat and the law of the equipartition of energy. This latter law (due to Maxwell, developed by Boltzmann and Rayleigh) was true in many cases, but had been found not to agree with all the observations. To understand the meaning of equipartition, one should think of bodies or systems capable of moving in different ways. If a point or atom could merely move to and fro, it was said to have one degree of freedom; if it could move in three directions it had three degrees of freedom of translational motion. There might further be vibrational and rotational movements, each with several degrees of freedom. The equipartition law now stated that after the disturbance had passed away and equilibrium conditions had been established, each degree of freedom, no matter of what type or family, would be found to have received from the disturbance the same amount of energy. That was true for gases like the air, in this sense, that the molecules of oxygen, nitrogen, helium, &c., had the same average energy. The most beautiful exemplification of the law was given by Perrin with regard to the Brownian movements of small particles of various sizes, suspended in liquids. The law also held for solids; for the atomic heat of all solids was approximately the same, subject to the reservation presently to be mentioned. But though applicable to molecules and atoms, the law did no longer hold for electrons, which had not all the same average energy.

Further to explain the discrepancy, Professor Jeans made use of other illustrations. When an organ pipe was blown it gave a fundamental note, and if blown harder, also the octave and other upper harmonics, representable by a series of tuning forks decreasing in size but increasing in frequency of vibration. When the wave-length was as small as the molecular distances the movements became a pure heat vibration, and the heat energy of a gas could be resolved into the energy of regular sound waves. That applied also to a solid, a string or wire vibrating as a whole or with one and more nodes in waves of decreasing length and increasing frequency.

In accordance with these arguments the atomic heat of all solids seemed to be the same and independent of temperature. That, however, recent low-temperature researches proved, was true only for ordinary temperatures about the neighbourhood of 300 deg. C. absolute. As the temperature sank below 200 deg. absolute the atomic heat decreased, more or less rapidly at first, and finally very slowly again as absolute zero was approached. The atomic heat curves for silver, copper and aluminium were exhibited. Thus the energy partition was not really the same, and the question was: What kind of partition of energy will yield the observed curves? By adjusting the scales of these curves P. Debye (Leyden) had succeeded in making all the atomic heats of these three (and also of other) bodies fall on one and the same curve; this theoretical curve was deduced from Planck's formula for the radiation of a black body. In this curve of Debye the specific heat of any (monatomic) solid appeared as function of T/θ, where T was the absolute temperature and θ a temperature characteristic of the element; θ could be calculated from the elastic constants, and T/θ was equal $1/x$, where $x = h\nu/RT$, h being Planck's universal constant, ν the frequency and R the gas constant. The total heat energy of a solid could be estimated from a knowledge of the specific heats at all temperatures, and this energy was exactly accounted for by assigning an average value of $RT.x/(e^x - 1)$ to each elastic vibration of a solid.

The explanation of Debye's curve and the general graph $x/(e^x - 1)$ was that the equipartition was not a universal law and not of absolute uniformity, the reason being that the equipartition theory was based upon the classical (Newtonian) laws of motion, which did not hold for low temperatures and high frequencies. The x became small for small ν and for high temperatures T; at low T, x was very large, and the amount of energy per degree of freedom became very small, as the study of the black-body radiation had shown. As stated, Debye went back to Planck, whose method of deduction had been criticised. But one could work back from the experimental curves, and Poincaré had shown that the experimental results inevitably led back to the $RT.x/(e^x - 1)$, and this in turn inevitably led back to the quantum theory. The lecturer himself had in vain attempted to explain the radiation laws on the basis of classical mechanics. Yet there was something very striking in the suggestion—which was the essence of Planck's quantum theory—that there could be no gradual continuous increase in energy, but only an increase in jumps, in whole multiples of $h\nu$. That suggestion was not so strange as it appeared, however. One had only to consider that under sufficient magnification no solid appeared to be continuous.

But the nature of the jump was more open to doubt, and the first question was, of course: Is there any direct evidence of energy in definite quanta or bundles? There was. When a polished metal was illuminated, nothing happened unless the frequency of that radiation exceeded a certain minimum value. Then only did electrons come off, the atoms of the metal being broken up. One might imagine that any light of lower frequency, if only of sufficient intensity or of sufficient duration, would have the same effect; but that was not so; quality, not quantity, was required. The atomic structure might be likened to that of a net of fine mesh; millions of small fishes could pass through without causing a disturbance, but one big fish would tear the net. When an atom was broken up, a certain amount of energy was spent in the ionisation, which sent off an electron at a certain measurable speed; the two amounts together made up one quantum of energy.

Thus the cloud that had prevented an explanation of photo-electric and other effects on the old views had been removed. But there were the optical effects, interference, diffraction, &c., which seemed to demand a continuous front of light waves, quite incompatible with energy radiation in separate bundles. It was, in fact, very difficult to reconcile the quantum hypothesis with the observed optical phenomena, for which the undulatory theory accounted. Before the quantum hypothesis was developed J. J. Thomson had himself suggested that the energy of light was not uniformly spread over the whole wave front, but concentrated at particular points.* The simplest way of attempting a reconciliation was perhaps to abandon the æther altogether, and to rely on the theory of relativity. But that explanation, again, did not go the whole way. On the other hand, the spectra of the elements and the arrangements of the lines in series (observed in the various regions of the spectrum) had been successfully approached on the quantum theory. This study had been taken up by N. Bohr in his "Attempts to Develop the Constitution of Atoms and Molecules on the Basis of Planck's Hypothesis for Explaining Black-Body Radiation." Bohr's atom consisted of a positively charged nucleus surrounded by a ring (in the case of hydrogen) or rings of electrons rotating about the nucleus in orbits of variable diameters. If some cause—for instance, the electric discharge in a vacuum tube—had removed the electron from the nucleus to a great distance, the atom would be re-formed by the binding of the electron, and the total amount of energy radiated out by the passing of the system from one of the

* We should refer our readers as to this feature and the relativity theory to ENGINEERING of August 11, 1916, page 132, and September 29, page 297.

* These views and the difficulties of the quantum theory were discussed by Sir J. J. Thomson last year; see ENGINEERING, vol. ci, page 380, April 21, 1916.

stationary states to another corresponded to multiples of $h\nu$, while the angular momentum of each electron in the permanent state was $h/2\pi$. The whole conception of this type of atomic structure, which general considerations had suggested, was only intelligible if the energy radiation was discontinuous—not continuous—and from such considerations Bohr had correctly calculated for many spectra the Rydberg constant (which was the same for all the different spectrum series), the ratio e/m (charge to mass of the electron). That conception of the atom had been carried further by J. W. Nicholson, who had indeed predicted the structure and spectra of unknown elements, the hypothetical coronium (a line in the sun's corona) and nebulium (in nebulæ). The Planck hypothesis thus had a large amount of experimental evidence to support it, and Professor Jeans certainly thought that there was something in it. Yet science was in a quandary. But very considerable progress had been made, and the new view of discontinuous motion should be followed up.

THE THEORY OF AIR-SCREWS.

AT the present time there appears to be no more promising theory of the air-screw than that introduced by Drzewiecki and further developed by Lanchester. In this theory the air-screw blade is regarded as being composed of a number of concentric strips, each of which is treated in the same manner as the wing of an aeroplane—that is to say, the lift and drag are calculated from wind-channel data on aerofoils, and the forces arrived at in this way are integrated over the whole blade area and resolved in a direction parallel to the axis of rotation to give the thrust, and at right angles to the axis to give the torque. The stresses in the blades can also be obtained in an obvious manner. An experienced designer using this method in conjunction with certain empirical constants can produce results which are generally sufficiently accurate for commercial requirements, and any small errors in design can usually be adjusted by a slight variation in the speed of the engine without materially affecting the efficiency. When, however, a careful laboratory test is made of a model propeller, and the experimental results are compared with those calculated by the theory outlined above, the agreement, although fairly good, is not all that could be desired. It is, therefore, evident that some of the assumptions of the theory are not justified.

In applying the theory to the design of air-screws it has been usual to assume that the blade entered still air, as although it was, of course, well known that the air in front of the screw was drawn in towards it, no data were available as to the magnitude of this inflow velocity and its distribution along the axis of the blade. The error due to this cause had therefore to be compensated for by the use of empirical correction factors. How the inflow velocity affects the problem is easily seen by comparing Figs. 1 and 2. Fig. 1, in which the inflow velocity is neglected, represents a section of an air-screw blade situated at a distance x from the axis of rotation, rotating at n revolutions per second, and having a translational velocity V ft. per second. The relative velocity of the air and the blade will therefore have a magnitude of $\sqrt{(2\pi nx)^2 + V^2}$ ft. per second in the direction O P, and the angle of attack, a, will be $\phi - A$, where ϕ is the angle the chord of the blade makes with the plane of rotation, and $A = \tan^{-1}\frac{V}{2\pi nx}$. Knowing the relative velocity of the blade and the angle of attack, the lift and drag on the blade element can be calculated with the aid of absolute coefficients obtained from wind-channel experiments. The lift L will be $C_y \cdot \rho \cdot b \cdot dx \cdot \sec^2 A\,(2\pi nx)^2$ and the drag D will be $C_x \cdot \rho \cdot b \cdot dx \cdot \sec^2 A\,(2\pi nx)^2$ where C_y and C_x are the absolute lift and drag coefficients, respectively, for the angle of attack a, b is the width of the blade, dx is the radial width of the element, and ρ is the mass per cubic foot of the air. The forces L and D act in directions at right angles and parallel to the direction of the relative velocity O P, and by resolving them in the direction of the translational motion we get the thrust T of the element = L cos A − D sin A. The torque, M = (L sin A + D cos A) x, is obtained by resolving the forces at right angles to the direction of the translational motion. The useful work will therefore be (L cos A − D sin A) V, and the work done will be (L sin A + D cos A) $2\pi nx$, so that the efficiency η of the element

$$= \frac{(L\cos A - D\sin A)\,V}{(L\sin A + D\cos A)\,2\pi nx}$$

or if R is the resultant of L and D and $\gamma = \tan^{-1}\frac{D}{L}$

$$\eta = \frac{V}{2\pi nx}\cdot\frac{R\cos\overline{\gamma + A}}{R\sin\overline{\gamma + A}} = \frac{\tan A}{\tan\overline{\gamma + A}}$$

If, however, the air is drawn into the air-screw with an axial velocity V_1 (see Fig. 2), the angle A will be increased to $A_1 = \tan^{-1}\frac{V + V_1}{2\pi nx}$, thus diminishing the angle of attack to a_1, and so altering the values of D and L to D_1 and L_1, since the coefficients C_x and C_y depend upon the angle of attack. The torque, thrust and efficiency of the blade element can be obtained in exactly the same way as above described, by substituting L_1 and D_1 for L and D, A_1 for A, and γ_1 for γ, and the corresponding quantities for the complete air-screw can be found by integrating over the whole blade length and multiplying by the number of blades. If this were done a much closer agreement between calculated and experimental values would be expected, and

Fig. 1.

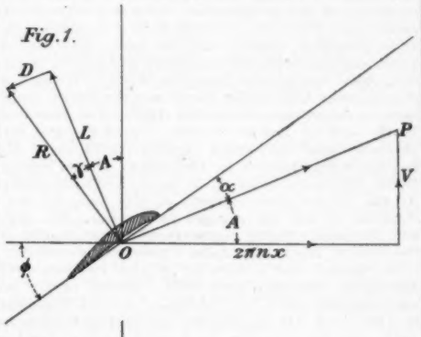
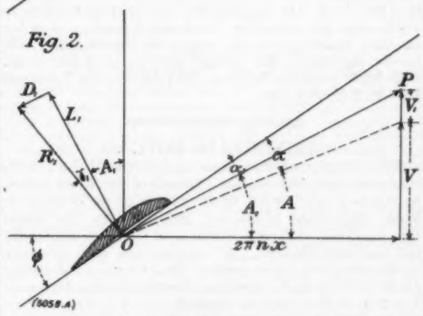


Fig. 2.



that this is actually obtained was stated by Mr. A. Fage, of the National Physical Laboratory, on March 14, in one of a series of educational lectures on aeronautics now being given, under the auspices of the Aeronautical Society, at St. Peter's Hall, Cricklewood, N.W.

In order to make the calculations as above indicated it is, however, necessary to know, or to make reasonable assumptions for, the values of the inflow velocity V_1 at all points along the blade axis, and in this connection considerable assistance may be obtained from a paper read before the Aeronautical Society on March 21 last by Mr. M. A. S. Riach which was an extension of the work already given in his book entitled "Air-Screws."* It is to this paper that we are indebted for most of the matter in the present article. Mr. Riach uses R. E. Froude's theory of screw propulsion, and equates the thrust on a blade element obtained from this theory to that obtained by the aerofoil theory, thereby getting the lift coefficient at the given radius in terms of the inflow velocity and consequently in terms of the real angle of attack. By plotting lift coefficients obtained in this way against angle of attack, and comparing the curve with that obtained for the same section by wind-channel experiments, it is possible to arrive at reasonable values for the inflow velocity at the part of the blade under consideration.

According to R. E. Froude's theory the thrust of a propeller is equal to the mass of the fluid passing through the propeller per second, multiplied by the difference between the velocity of the slip stream and the translational velocity of the propeller. Now if V be the translational velocity, V_1 the inflow velocity, and V_2 the velocity added to the fluid by the propeller, the slip-stream velocity will be $V + V_1 + V_2$, and the thrust $T = M(V_1 + V_2) = M V_1\left(1 + \frac{V_2}{V_1}\right)$. Now the fluid enters the screw at a velocity $V + V_1$, and the mass of air passing per second through an annulus of width dx, and of radius x, will be $2\pi x\,dx\,\rho\,(V + V_1)$. If we introduce a coefficient q to represent the fraction of the annular element employed, the mass will be $q\,2\pi x\,dx\,\rho\,(V + V_1)$, and the thrust on the element becomes

$$dT = q\rho\,2\pi x\,dx\,(V+V_1)\,V_1\left(1 + \frac{V_2}{V_1}\right)$$

$$= q\rho\,2\pi x\,dx\,(2\pi nx)^2\tan A_1\,(\tan A_1 - \tan A)\left(1 + \frac{V_2}{V_1}\right).$$

On the aerofoil theory the thrust on each blade element = $L_1\cos A_1 - D_1\sin A_1$, and since $D_1 = L_1\tan\gamma_1$

$$dT = N L_1(\cos A_1 - \tan\gamma_1\sin A_1)$$
$$= N L_1\cos A_1\,(1 - \tan\gamma_1\tan A_1).$$

where N = the number of blades employed. Substituting for L_1 its value

$$C_{y_1}\,\rho\,b\,dx\sec^2 A_1\,(2\pi nx)^2$$

we have

$$dT = N C_{y_1}\,\rho\,.\,b\,.\,dx\sec A_1\,(2\pi nx)^2\,(1 - \tan\gamma_1\tan A_1).$$

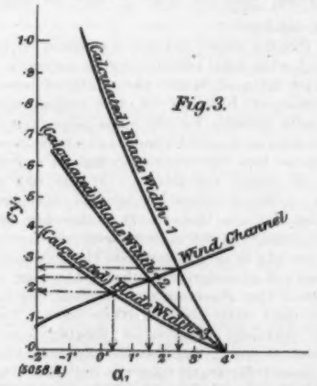
Equating the two expressions for the thrust we get

$$C_{y_1} = \frac{q\,2\pi x\sin A_1\,(\tan A_1 - \tan A)\left(1 + \frac{V_2}{V_1}\right)}{N\,b\,(1 - \tan A_1\tan\gamma_1)},$$

and this expression, when employed in conjunction with the wind-channel graph of C_{y_1} against a_1, is sufficient to solve for both of these variables. The two unknown quantities q and V_2/V_1 in the above equation may both, Mr. Riach suggests, be taken, as a first approximation, as being equal to unity, that is to say, he assumes that the whole area of the annulus is utilised, and also that half of the acceleration of the air takes place in front of the screw and the other half behind it, in accordance with R. E. Froude's hypothesis.

It may be interesting to note here that the theory shows that if the pitch ratio (V/nd) be kept constant the ratio $\frac{V + V_1}{V}$ will also be constant, *i.e.*, for a given value of the pitch ratio the ratio of the velocity with which the air enters the screw to the translational velocity will be constant—a result which has been established experimentally by Eiffel in his tests on model air-screws. Another interesting feature can be brought out by a study of Fig. 3, in which the values of C_{y1}, obtained as above described, have been plotted against angles of attack for three different blade widths, the

Fig. 3.



section of the blade remaining constant. The curves show that if the blade width be doubled the ordinates of curve 1 are halved, and the values of C_{y1} and a_1 are both reduced. This increases A_1, and also, probably, increases γ_1. A new value of the thrust on the element can then be obtained by

* Published by Crosby Lockwood and Son.

substituting in the formula $d\,T = C_{y\,1}\,\rho\,b\,dx\,4\pi^2n^2x^2 \sec A_1\,(1 - \tan A_1 \tan \gamma_1)$, but the new thrust will be considerably less than double the old value. This loss, Mr. Riach considers, is due to the fact that the higher inflow velocity reduces the angle of attack, and though the increase in V_1 would produce an increase in thrust if the ratio $\frac{V_2}{V_1}$ remained constant (but not a *proportionate* increase in thrust, even if $\frac{V_2}{V_1}$ did remain constant), this ratio is altered by changes in the angle of attack, and may become zero, or even negative, for small or negative values of a_1. Again, it is evident that the efficiency $\frac{\tan A}{\tan (A_1 + \gamma_1)}$ of the element will be diminished by the increase in A_1 and γ_1 following on an increase of blade width, though matters might be considerably improved by increasing the chord angle ϕ so as to give the angle of attack a value corresponding to the minimum value of $\frac{D}{L}$.

With regard to the losses at the ends of the blade, it may be taken that those at the boss end are negligibly small, but those at the blade tips must be taken into account in estimating the power required, thrust and efficiency. For this purpose Mr. Riach assumes that the maximum intensity of pressure occurs about half way along the blade, and that the pressure falls off to a minimum value at the boss and tip. With these assumptions it is possible to make some allowance for the relative changes in lift, and in the ratio of lift to drag, which occur along the blade, and thus to arrive at results which, if not exact, are at all events more accurate than could be obtained if pressure distribution were ignored. We have also to make some allowance for the variation of the ratio $\frac{V_2}{V_1}$ along the blade, as it is fairly obvious that the ratio cannot remain constant and equal to unity over the whole area of the screw disc. According to Mr. Riach its value will usually be considerably less than unity, and he suggests that it may be taken as being equal to the ratio of the pressures on the lower and upper surfaces of an aerofoil. If this view be accepted and applied to all points along the blade axis, it is possible completely to analyse an air-screw under any set of conditions. For instance, when the air-screw is giving no thrust we have $d\,T_1 = L_1 \cos A_1 - D_1 \sin A_1 = 0$, so that $\frac{D_1}{L_1} = \cot A_1$ and, as the ratio $\frac{D_1}{L_1}$ is known from wind-channel experiments, a_1 can be found by subtracting A_1 from the blade angle ϕ. Again, since $d\,T = q\,\rho\,2\,\pi\,x\,d\,x\,(V+V_1)\,V_1\left(1 + \frac{V_2}{V_1}\right)$ either $V_1 = 0$ or $\frac{V_2}{V_1} = -1$, *i.e.*, either there is no inflow or else the pressures on the upper and lower surfaces of the blade are equal and opposite. The latter condition is well known to occur on aerofoils at small negative angles of attack, so that the assumption that the ratio $\frac{V_2}{V_1}$ may be negative is not unreasonable.

Mr. Riach's paper includes a solution on the new theory for the total efficiency of an air-screw having a special form of blade, the width of which is a mathematical function of the radius, and also contains a formula for the horse-power required to sustain a given weight by means of a helicopter. He also shows how the correction factors required for practical design calculations on the old aerofoil theory, in which inflow is neglected, may be calculated by the new theory. It is therefore possible, by comparing the calculated correction factors with those already in use, to estimate the accuracy of the new method of design. We have, however, already exhausted the space at our disposal, so that we cannot deal with these matters here. The new theory certainly involves a greater amount of arithmetical work, but the obvious fact that it is much nearer the truth than the old theory will, we think, more than outweigh this objection. There is still some uncertainty as to the allowance to make for losses at the blade tips, and further experimental information regarding the values of $\frac{V_2}{V_1}$ is also needed. The theory, however, clearly brings out the importance of using high aspect ratios (*i.e.*, multiple blades), with good sections having high values for $\frac{L}{D}$ in order to obtain the maximum efficiency, so that it appears to be worthy of careful consideration by air-screw designers.

THE LATE MR. EDWARD HAYES.

WE regret to have to announce the death, which occurred on the 5th inst., at Mansfield, Stony Stratford, Bucks, of Mr. Edward Hayes. Mr. Hayes was the head and only member of the well-known firm of shipbuilders, Watling Works, Stony Stratford, and 9, Bridge-street, Westminster; he was the eldest son of the late Mr. Edward Hayes, also of Stony Stratford, and was born in 1845. He entered the engineering profession in 1863 as a pupil under his father at the Watling Works, where he remained for four or five years. He was subsequently engaged in the construction of small steam vessels and machinery on the River Weaver over a period of about three years, being later employed by the late Mr. Thomas Graham, Leamington, upon canal survey and in experimenting with light-draught vessels on canals and rivers. From 1869 to 1876 he took part in the management of the Watling Works, during which time he was engaged on various enterprises in connection with marine engineering and the building of small steam vessels.

On the death of his father the Watling Works were left to Mr. Hayes, and they remained in his possession ever since. During his ownership the firm was employed in the construction of marine engines and small steam vessels up to about 80 ft. in length, chiefly screw-propelled vessels, built of steel. Numbers of these, together with stern-wheelers and paddle boats, have been sent abroad from the Watling Works. A steam yacht built by Mr. Hayes won the International race at Argenteuil, France, in 1889. The Board of Works and the London County Council engaged Mr. Hayes to build their steam tugs for the Thames. He has also built steamers for the Sailors' Home, Trinity House Pilots, and other public bodies and institutions. At the present time upwards of fifty steamers constructed by him are engaged in the war. We may add that many young engineers who were trained at the Watling Works have risen to positions of eminence.

Mr. Hayes was a member of the Institution of Mechanical Engineers since 1878; he was elected an associate-member of the Institution of Civil Engineers in 1883, and was transferred to full membership in 1892. He has been for the last 40 years a member of the Watling Street Lodge of Freemasons. He leaves two sons, Mr. Arthur Hayes, A.M.Inst.N.A., who takes over the business, and Lieutenant Laurence Hayes, 20th Punjabis.

INDUSTRIAL NOTES.

THE Minister of Munitions, in exercise of the powers conferred upon him by the Defence of the Realm Acts, has issued an Order with reference to dealing in lead. Maximum prices are also fixed in the Order for pig lead, manufactured lead, lead compounds, red lead and litharge. All applications with reference to the Order should be made to the Director of Materials (A.M.2. (E.)), Hotel Victoria, Northumberland-avenue, London, W.C. 2, and be marked "Lead Licence."

We are informed that the North-East Coast engineers' ballot on the award of the Committee on Production for an advance of 2*s.* per week on time rates and a proportionate advance on piece rates, which would come in operation as from February 1, is proceeding favourably for acceptance. The men affected number from 25,000 to 30,000.

We read in *The Iron Trade Review*, Cleveland, Ohio, that the bi-monthly examination of sales sheets of selected mills manufacturing bar iron, sheets and tin-plate, made on March 10, at Youngstown, by officers of the Amalgamated Association of Iron, Steel and Tin Workers, and by manufacturers' agents, showed price averages considerably above those previously prevailing. The average price of bar-iron in January and February was 2.35 cents, entitling puddlers to 11.30 dols. a ton for boiling in March and April, an increase of 1 dol. per ton above the rate that prevailed during the first two months of 1917. Bar-iron mill wage rates are the highest in the history of the trade in America.

The average sales price of Nos. 26, 27 and 28-gauge steel sheets was found to be 3.40 cents, as against 2.80 cents in the preceding bi-monthly period. Wages of sheet mill employees in March and April will be 18 per cent. above the rates prevailing in January and February, and 37.5 per cent. above base.

Tin-plate, during the first two months of the year, sold at an invoiced average price of 4.95 dols. a box, giving employees in the tin-plate division an additional wage increase of 14 per cent. Wages of tin-plate employees in mills working under the wages scale of the Amalgamated Association are 29 per cent. above base. Wages prevailing in mills recognising the Amalgamated Association will be offered in other plants, as has been the case for several months.

We learn from *The Birmingham Daily Post* that the national alliance between employers and employed, which was inaugurated in Birmingham a month or two ago, does not apparently commend itself to the bulk of trade unionists, although several of their prominent leaders support the movement. By a decisive vote the Birmingham Trades Council, on Saturday, the 7th inst., repudiated the alliance, notwithstanding strong arguments in its favour by Councillor Beard and one or two other delegates.

The subject was introduced by Mr. A. Shakespeare (National Union of Railwaymen, Birmingham No. 4 Branch), who moved:—

"That this council decides to dissociate itself with the proposals for a national alliance between employers and employees, believing that the dangers of such an alliance outweigh the advantages, and further desires to emphasise that any attempt to prevent the restoration, after the war, of trade union rights and privileges, or their equivalent, will be opposed in the strongest possible manner."

Having stated that the probable reason why the executive had given them no definite lead on this subject was because they thought the alliance would die a natural death, Mr. Shakespeare said circumstances which had occurred proved that these anticipations were not going to be fulfilled. It was reasonable to conclude that the promoters of the alliance would not have taken the trouble and made the efforts they had if they feared it would break down at the first criticism. His union had turned the alliance down.

A sinister motive, he was convinced, was at the back of it, and that was, as mentioned in the latter part of the resolution, to prevent the restoration of trade union rights and liberties at the close of the war. The men who convened the meeting in the Central Hall were not, so far as he was aware, the friends of labour, and doubt of them, which many workers felt, was increased when they read sinister paragraphs in the press and heard statements from public platforms to the effect that they would never be able to return to pre-war conditions. There was talk about better relations between employers and employed, but for his part he, as a railwayman, did not entertain any better feeling towards his employers. Though not an advocate for always having war between labour and capital, he could not support the alliance because in it he saw an insidious move on the part of capitalists. When the war was over the same old class distinctions would arise. If there was any alliance to consider it should be among workers.

Mr. W. Davis (R.L. Insurance Agents) seconded, arguing that the existence of Factory Acts was evidence of the antagonism between public good and private profit. Any trade unionist who supported a national alliance between employers and employed must be singularly blind to industrial history.

Councillor Beard denied the competence of the Trades Council adequately to deal with the question. It was purely a domestic matter for the unions to take up. There appeared to be an entire misapprehension as to what was meant by the alliance. Perhaps the term was a misnomer. Knowing something of the genesis of the movement, he could tell them that if the Government were left to deal with unemployment immediately after demobilisation it would be badly done, and therefore it was advisable for employers and workmen's representatives to come together and discuss matters. That was a business-like way and there was nothing insidious about it. The alternative to conferences was to fight and to fight always. And that they could not always do. He did not see that the council had anything to do in the matter, and he suggested the resolution should be withdrawn.

The resolution was then put, with the result stated above.

A conference was held at the Wigan office of Sir Thomas R. Ratcliffe-Ellis (secretary to the Coalowners' Association) on Saturday, the 7th inst., between representatives of the Lancashire and Cheshire Coal-owners' Association and representatives of the Joint Council of Colliery Workers outside the Miners' Federation, consisting of Lancashire and Cheshire Enginemen and Boilermen, Lancashire and Cheshire Colliery Firemen, and other organised colliery workers. The question for consideration was the effect which the arrangements come to between the coalowners and the Miners' Federation in regard to the operation of the Daylight Saving Act would have upon the organised colliery workers outside the Miners' Federation.

The arrangements between the representatives

constituting the Lancashire and Cheshire Joint Committee are as follow, says *The Newcastle Daily Chronicle* :—

1. After the coming into operation of the Daylight Saving Act (April 9, 1917) and during its continuance the hours of work on each day of the week, except Friday and Saturday, shall be from 7 a.m. to 3 p.m. ; on Friday, from 7 a.m. to 4 p.m. ; and on Saturday, from 7 a.m. to 1 p.m.

2. At collieries where in any week the Saturday is not a working day at the pit the extra hour, if worked, on Friday shall be paid for as one-seventh of a day.

3. Where Saturday is a working day at the pit a workman who is absent from work on the preceding Friday, but works on Saturday, shall only be entitled to be paid six-sevenths of a day for such Saturday.

4. In cases where work now commences at 7 a.m., and the majority of the workmen employed at the colliery desire the present hours of work and conditions to continue, no alteration in the existing hours and conditions shall be made.

5. The management and the majority of the workmen employed at any colliery may, in lieu of the above arrangement, adopt the practice and conditions now prevailing at collieries where the hour of the commencement of work is 7 a.m. and not 6 a.m.

After discussion an agreement was arrived at by the conference in regard to the organised colliery workers outside the Miners' Federation and the operation of the Daylight Saving Act, on the accepted principle that any arrangement come to by the organised coalowners and the Miners' Federation, if it affected the organised colliery workers outside the Miners' Federation, could not take effect unless by agreement between the representatives of such organised colliery workers as were affected and the coalowners.

In regard to enginemen and boilermen the terms agreed upon by the conference were :—

1. All winders and other enginemen working on the loose and tie system to change shifts as hitherto ; exceptional cases to be considered by the management and the enginemen's representatives.

2. All two or single-shift winding enginemen to alter their time of coming on duty according to the new time arrangements between the Coalowners' Association and Miners' Federation for April 9, 1917 ; in all other cases of enginemen, including also locomotive men, exceptional cases to be considered by the management and enginemen's agents.

5. All stokers working on the loose and tie system, where there is the same number of stokers on each shift, to change shifts as hereto ; but where there is a larger number of stokers employed on the day shift than on either of the other two shifts, then the time of changing shifts to be altered according to the new time arrangements as stipulated for enginemen in Clause 2 ; exceptional cases to be considered by the management and the enginemen's agents.

It was agreed that the arrangements with the Miners' Federation and other workmen did not involve any change in colliery tradesmen's hours.

The representatives of the Lancashire and Cheshire Colliery Firemen's Association agreed to conform with the change in hours providing the agreement did not affect the wages of colliery firemen, and this condition was accepted.

THE MANGANESE ORE OUTPUT OF BRAZIL.—Our American contemporary, *The Iron Age*, reporting from other sources, gives the following figures for the Brazilian output of manganese ore :—

	Metric tons.
1912	154,870
1913	122,300
1914	183,330
1915	288,671
1916	503,130

While 1915 showed a decided increase over 1914, due to the cutting-off of European supplies of the ore, the output in 1916 was almost double that of 1915 and nearly triple it in value, the 503,130 tons having a valuation at Rio de Janeiro of about $7,180,000, or more than $14 per ton.

AMERICAN COPPER EXPORTS.—The American exports of copper in 1916, says *The Iron Age*, New York, while not as large as in 1913, a record year, were nevertheless of very large proportions when it is considered that Germany, America's previously largest customer, is unable to buy any. The following table, compiled from Government data, illustrates this :—

Calendar year.	Gross tons.
1913	413,500
1914	375,036
1915	304,026
1916	350,046

Of the 413,500 tons exported in 1913 Germany took 137,120 tons, or one-third, so that in reality the 350,046 tons exported in 1916, when none went to Germany, is proportionally a greater rate than ever before. Of the 1916 exports France took 150,370 tons, whilst 82,395 tons went to the United Kingdom, 50,787 tons to Italy, and 22,169 tons to Holland.

THE PHYSICAL SOCIETY OF LONDON.

AT the meeting held on Friday, March 9, at the Imperial College of Science, Professor C. V. Boys, F.R.S., President, in the chair, a paper entitled "*To Measure the Pressure in a High Vacuum by Observations of Logarithmic Decrement*," by Dr. P. E. Shaw, B.A., D.Sc., was taken as read in the absence of the author.

In experiments on the Newtonian constant (Phil. Trans., May, 1916) the author used a torsion balance in a vacuum which varied in different cases from 15 mm. to 0.00001 mm. pressure. Before sealing the vessel the pressure was determined by a McLeod gauge. Values of the pressure after sealing-off were deduced, in the case of the higher vacua, from observations of the damping of the torsion system.

The formula employed is due to the late Professor Poynting, and can be expressed in the form—

$$P = 35.6 \frac{I}{s\,a\,T} \lambda$$

where I = moment of inertia of suspended system, s = area of surface (supposed plane) which is experiencing the resistance, a = mean distance of plane from centre of rotation, T = period of oscillation, and λ = the observed logarithmic decrement.

In the paper a table and curve are given showing the relation between P and λ.

A paper on "*A Diffraction Colour Box*" was read by Mr. A. W. Clayden, M.A.

The apparatus consists essentially of a very simple concave grating spectroscope, of which the slit and grating are situated at opposite diameters of a circle, the spectrum being formed on the arc of this circle. Two independent arms carry fittings on which may be placed either telescope eyepieces or small electric lamps. With the slit of the instrument illuminated by a suitable source, the eyepieces can be set so that any two desired wave-lengths are in the centres of their respective fields of view. The eyepieces are then replaced by the small lamps (the filaments coinciding with the previous positions of the cross-lines), and the grating is observed with a small telescope pointed towards the widened slit ; the whole of its surface is seen to be illuminated with a mixture of the two colours on which the eyepieces were originally set.

The "concave grating" employed consists of a Thorpe replica of a Rowland plane grating of 14,475 lines to the inch, mounted with its ruled surface in contact with the surface of a concave mirror of 4 ft. focal length. This forms an admirable substitute for the more expensive concave grating.

The author prefers to state results in terms of the number of oscillations per unit of time. Observations showed that the smallest change of wave-length which could be recognised by the eye as a change of colour was greater than that which corresponded to a change of period of 10^{13} vibrations per second, or to a change of one vibration more or less in $1/10^{13}$ second.

Mr. Trotter asked how the minimum difference of wave-length detectable as colour difference compared with the values obtained by Dr. Edridge-Green.

Mr. T. Smith said that experiments on the minimum colour difference which the eye could detect were valueless unless the exact conditions under which the experiments were made were stated. For example, the comparison of two colours side by side is materially affected by the presence of a black space between them. In Dr. Edridge-Green's experiments the conditions were not good. The experiments were made somewhat as follows :—While viewing the extreme red end of the spectrum a shutter was brought down towards the red so as to cut off everything above the region to which the observer would give one distinguishing name, such as deep red. A second shutter was then brought up from the red end to cut off the first patch, and the first shutter moved along the spectrum until the boundary of the next "monochromatic" patch was located. By this means the whole spectrum was divided up into about 25 monochromatic patches. It was not difficult to repeat these observations, but if they were compared with measurements made in another way entirely different results were obtained. Lord Rayleigh was able, for instance, to distinguish between the colour of the two sodium lines. He had two spectra, one above the other, the upper one being inverted, so that D_1 and D_2 of one spectrum coincided with D_2 and D_1 of the other. Colour comparisons should always be made from simultaneous observations of the two colours.

Professor C. V. Boys said he would like to emphasise Mr. Smith's remarks about the effect of varying conditions on the visual estimates of colour. In the colours of soap films, for instance, this difficulty is met with. Where the thickness is nearly zero the colour is black. As the thickness increases the colours of the first order are successively encountered. Between the blue and yellow there is a tint which can only be described as a bad white. He had long been puzzled as to what this colour was, but had eventually discovered a method of overcoming the deceptive influence of the adjacent colours. Usually these films are traversed by long thin folds. The thickness of the folded film is everywhere three times that of the adjacent unfolded film. Points can be found where this doubtful region between the blue and yellow, occurring on the triple film, can be directly contrasted with the first order white in the adjacent single film. It is then seen to be a very good green. A point which had surprised him in connection with Mr. Clayden's apparatus was that the plane grating, which could not be in actual contact with the mirror except at its edges, nevertheless behaved as if it were in good optical contact.

Dr. W. Eccles pointed out that the minimum colour difference estimated by Mr. Clayden to be perceptible to the eye, if expressed in the same way as an interval in music, works out as about 1.0013. The tone difference just perceptible to the trained musical ear has been stated to be one seven-hundredth of an octave, which works out as 1.001. It is interesting to observe that the sensitiveness of the eye to pitch difference is, like its sensitiveness to inflow of energy, of the same order as that of the ear.

Mr. Clayden, in reply, said that in making his experiments on the minimum difference of wave-length required to produce a noticeable change of colour he had arranged matters so that by using a reversing or non-reversing eyepiece in the observing telescope one or other colour was uppermost in the field of view. The difference in wave-length was then reduced until it was impossible to say which was which. By this method he could detect a difference of two vibrations per $1/10^{13}$ second, but at the red and violet ends of the spectrum the detectable difference greatly increased. With regard to the president's last remarks, he had himself been very agreeably surprised to find that the performance of the grating was so satisfactory.

An arrangement for showing by projection on a screen the coloured fringes exhibited when a Thorpe grating is laid with its ruled face against a plane mirror was shown by Mr. A. W. Clayden. In this the light from a small lantern is incident in an approximately parallel beam on the interface of the grating and mirror, which are held together in a wooden framework supported on a stand. The position of the grating-mirror combination is adjusted so that the central reflected beam, or any one of the diffracted beams, is returned just alongside the lantern. The beam passes through a projection lens which focuses the fringes on a distant screen. The fringes thus obtained are very bright, and the simplest apparatus and adjustments suffice for their production.

Dr. R. S. Willows mentioned that Fellows had informed him that these fringes had been described by Barus in the *Philosophical Magazine* (July, 1910, and July, 1911). He understood that they had also been exhibited by Rheinberg at the Optical Convention in 1910. Mr. Clayden's method of exhibiting them by projection would, he thought, be distinctly useful to teachers.

An apparatus for studying the effect of Hertzian waves on the heart was exhibited by Professor W. M. Coleman.

A simple pendulum, consisting of a cylindrical brass bob terminating in a pointed wire co-axial with the bob, hangs by a piece of string above one of the terminals of an induction coil, so that in its lowest position the point of the bob is within sparking distance of the terminal and vertically above it. The bob is connected by a piece of flexible wire to the other terminal of the coil. When the pendulum is set oscillating there is a shower of sparks every time the bob passes its lowest position. The frequency of intermittence can be varied by altering the length of the suspension. By adjusting the period of the pendulum nearly to the time of a heart-beat any possible effect on the rate of the beating may be observed. The condensed discharge from two Leyden jars is employed.

FOREIGN ENGINEERING PROJECTS.

WE give below a few data on several foreign engineering projects, taken from the *Board of Trade Journal*. Further information on these projects can be obtained from the Commercial Intelligence Department, 73, Basinghall-street, London, E.C.

Chile.—The *Diario Oficial*, Santiago, publishes a Law (No. 3,185), granting authority to the President of Chile to draw up the regulations under which water-supply systems in the Republic which have been, or may be, financed by the Government will be exploited and conserved. The Law also assigns the amounts to be devoted to the carrying out of water-supply improvements and the installation of new systems in various towns of the Republic during the years 1917–27. 1917 : A sum of 1,220,000 pesos (paper) is assigned for waterworks improvements at San Felipe and Los Andes, Coquimbo and Serena, Ovalle, Rencs, Rancagua, Curicó, Lináres, Cauquenes, Concepcion and Talcahuano, Cañete and Puerto Montt, and the installation of systems at Illapel, La Union, Bulnes, Molina, Cartajena and San Antonio, and Llolleo. 1918 : Improvement works are to be effected at San Felipe and Los Andes, Coquimbo and Serena, Ovalle, Rencs, Rancagua, Peumo, Curicó, Lináres, Cauquenes, Concepcion and Talcahuano, Cañete and Puerto Montt, while installation works are to be carried out at Illapel, Tocopilla, Taltal, Vichuquen, Lautaro, La Union, Búlnes, Molina, Cartajena and San Antonio. The total sum allotted for the works is 1,675,000 pesos. 1919 : The expenditure for the year is put at 1,660,000 pesos, covering improvements at San Felipe and Los Andes, Coquimbo and Serena, Curicó, Lináres, Cauquenes, Concepcion and Talcahuano, and Milipilla, and installation works at Illapel, Tocopilla, Taltal, Calera, Lautaro, Nueva Imperial, La Union, Búlnes, Cartajena and San Antonio, and Pitrufquen. 1920 : An expenditure of 1,670,000 pesos is provided for. Improvements are to be undertaken at San Felipe and Los Andes, Coquimbo, Serena, Curicó, Concepcion and Talcahuano, Milipilla and Chanco, and installation works at Illapel, Salamanca, Tocopilla, Taltal, Calera, Lautaro, La Union, Búlnes, Achao, and Pitrufquen. Each year preference will be given to the installation of systems in departmental capitals having no water-supply service. Particulars regarding the projected expenditure in each of the years 1921–27, and the names of the places at which works are contemplated, may be consulted by United Kingdom firms interested at the Department of Commercial Intelligence. (1 peso paper = about 10*d*.)

WATER SUPPLY IN WESTERN AUSTRALIA.*

The Coolgardie Water Supply, Western Australia.

By P. V. O'Brien, M.Inst.C.E., and J. Parr, B.Sc. Assoc.M.Inst.C.E.

The construction of the Coolgardie waterworks was described by Mr. C. S. R. Palmer in a paper read before the Institution in 1905, and the object of the present paper is to review the works to date.

The water pumped at the first pumping station has increased from a little under 1,000,000 gallons per day for the year 1903 to 3,300,000 gallons per day during the past two or three years. Of this quantity about one-fifth is accounted for in the agricultural areas traversed by the main, and four-fifths in the mining areas, but only three-fifths reaches Kalgoorlie. The total length of branch and reticulation mains now laid in the goldfields district is about 236 miles, and in the agricultural areas about 628 miles. To minimise corrosion the water has been treated with lime since 1910, and additional tanks have been erected at several summits to keep the main full of water. Additional storage tanks have also been provided at pumping station No. 5, and at Kalgoorlie, and arrangements are now in hand to de-aerate the water before it enters the main.

The Reservoir.—There has been at all times an ample supply of water available in the reservoir.

The principal substances in solution in the water are the chlorides of sodium and magnesium. The salinity increases each year from September to June, and falls more or less during July and August, according to the quantity of water flowing into the reservoir. A series of dry years naturally increases the salinity. The lowest salinity was recorded in October, 1905, viz., 4 parts of chlorine per 100,000, equivalent to 4.6 grains of sodium chloride per gallon, and the highest in January, 1915, 30.2 parts chlorine per 100,000, or 35 grains of sodium chloride per gallon.

The Weir.—The wall generally is in good condition and the seepage through it is slight. Three bore-holes sunk in the wall in 1914 showed a general slow infiltration of water through the wall and comparatively free flows at certain levels corresponding with horizontal lines of seepage on the down-stream face. Under such conditions the upward water pressure in the wall must be taken into consideration in estimating the stability.

The Pipe-Line.—The lead joints have generally given good results, but in a few cases the frequent re-caulking of weak joints has caused rapid local internal corrosion and has rendered the removal of the pipes necessary. The locking-bar joints have stood well, and only in one case has a bar failed. In 1905 a leak occurred through external pitting, and since then there has been a gradual increase in the number of such holes each year. Wherever they occur the pipes are uncovered and supported on timbers clear of the earth. They are left open, and are found to keep generally in good condition at moderate cost. The original bituminous mixture on the exterior of the pipes underground has practically all perished, but where the pipes are above ground it (and consequently also the pipes) shows very little depreciation. Where the pipes were laid underground in gravel or sand they show slight rusting only, but in loamy and clay country, which is generally salt, a considerable amount of pitting and scaling has been found.

The carrying capacity of the various sections of the main decreased for a number of years, till it reached limits ranging from 33 per cent. to 60 per cent. below the original capacity; since then it has remained practically constant. In consequence of the lime treatment of the water a deposit, chiefly of carbonate of lime, has taken place in the main, ranging in thickness from about $\frac{1}{8}$ in. at Mundaring to traces only at Kalgoorlie.

Nodules of rust have been found on almost every pipe examined, and, without exception, they are more numerous on one side of the pipe than on the other. The side carrying the most nodules is apparently the side which was most exposed to the sun whilst the pipes lay on the ground before being laid, and has no connection with the present position of the pipe or the thickness of the bituminous coating. The nodules vary in number up to 90 per square foot on the worst pipe. The height of the largest nodule on the pipes was found to be $1\frac{1}{2}$ in. The coating was found to have perished and to be porous to a depth of $\frac{1}{64}$ in., but beyond that it was in good order. The formation of the nodules appears to arise from cracks in the bituminous coating rather than from the gradual decay of the coating, for a close connection is apparent between the condition of the pipes and the severity of their exposure before being laid, whilst at the same time every pipe shows areas without nodules where the coating is thin and must have perished years ago. Under every nodule there is a corresponding pit. As a general rule a few pittings up to $\frac{1}{4}$ in. deep were found in the pipes wherever an inspection was made. In a few cases pipes were found practically free from pitting, whilst in a few others pittings over $\frac{1}{4}$ in. and up to $\frac{1}{2}$ in. deep were found. Where the pittings were $\frac{1}{2}$ in. deep they were isolated, about $\frac{1}{2}$ in. diameter, and surrounded with metal of the full original thickness and carrying mill-scale.

Corrosion.—Pitting starts wherever the water gets access to the steel and an adjoining layer of scale—thereby constituting a galvanic battery—and the depth of the pit will depend on the time taken to separate the piece of scale from the plate and thus destroy the element. Large areas of mill-scale and punctures in a thick bituminous coating are conditions highly favourable to deep pitting. The corrosive quality of the water appears to be due chiefly to its dissolved oxygen and carbon dioxide. The variations in the quantities of the salts found in the water make no appreciable difference in the corrosive quality. As the water passes along the main it loses over two-thirds of its dissolved oxygen and shows decreasing corrosive activity.

Life of the Main.—This will probably be determined either by leaks due to internal corrosion or by external corrosion close to the lead joints. The worst internally corroded pipe so far discovered shows a reduction in thickness along a strip 4 in. wide and the full length of the pipe, amounting to about 0.007 in. per annum. Such a pipe would probably have a further life of about 10 years under similar conditions. By de-aerating the water, in addition to treating with lime, internal corrosion can probably be reduced.

The capacity of the main between pumping station No. 4 and Kalgoorlie appears likely to meet all requirements for many years, but between stations Nos. 2 and 4 the quantity of water to be pumped is increasing every year, and it will probably be necessary in a few years to improve the capacities of these sections by overhauling some of the pipes or laying new ones.

The Pumping Plants.—On account of the increase in the friction in the main it has been necessary to reduce the sizes of the plungers at several of the pumping stations, and the capacity of the pumps has been reduced accordingly from 6,000,000 gallons per day to 4,000,000.

The cost of pumping, including wages, salaries, fuel, oil, &c., repairs, renewals, alterations and maintenance of buildings and quarters is 0.27*d.* per 1,000 gallons lifted 100 ft.—equivalent to 0.57*d.* per effective or pump horse-power-hour. Taking the total quantity of fuel burned in the boilers for the past twelve months, the working duty of the plants is about 90 per cent. of that guaranteed.

The whole of the pumping plants have kept in good order and have suffered only the usual wear and tear, requiring only minor repairs.

* Abstracts of two papers read before the Institution of Civil Engineers on Tuesday, April 3, 1917.

Water Supply in the Interior of Western Australia.

By P. V. O'Brien, M.Inst.C.E.

Physiographically, West Australia is divided into three districts, namely, the coastal plain, the coastal ranges, and the Plateau of the Interior, and geographically into six divisions, the aggregate area of which is 976,000 square miles. Temperatures vary with the distance from the coast, with latitude to some extent, and also with the prevailing winds. Generally the inland plateau is intensely hot in summer and cool in winter. The atmosphere is dry, the evaporation great, and the rainfall very low. Rivers in the north-west of the State carry water only after heavy tropical rains, and then for a short period only. With the exception of the extreme south-west division, no perennial streams or fresh-water lakes exist.

Scattered over the interior are numerous salt lakes ranging in area from a few acres to 1,000 sq. miles. There is little doubt that these chains of salt lakes were at one time flowing rivers, but have altered owing to the rising of the land and the change of climate. The mineral belts, chiefly auriferous, stretch from the south coast, with a few breaks, to the nothern or Kimberley division. A great many mineral finds were made in the early nineties, and a large influx of population occurred. Many finds have also been made since the great gold rush, and there is little doubt that many more will be made in the future.

The rush of population mentioned above resulted in hundreds of mining camps springing up, many of which grew rapidly into prosperous towns. These, with the scores of smaller townships, are supplied with fresh water, and ore-treatment plants on mines are supplied with salt or fresh water, or both. Roads, railways and stock routes followed settlement, and water supplies were generally kept ahead of settlement. Artesian basins exist, but do not extend to the interior. Therefore other sources of supply were looked for, and found in subterranean water at depths varying up to 200 ft., and in conservation of rain water. Over the greater part of the Central division the ground water is salt. During the first few years of the gold rush this water, being the only kind procurable, was distilled and sold at 4*d.* per gallon. No distillation has been necessary since 1900.

Salt-Water Wells.—Salt water is used in ore crushing and for other purposes on mines. Heavy flows cannot always be found just where required, and in such cases it has been necessary to pump from various distances, up to 18 miles from the source of supply to the mines.

Fresh-Water Wells.—North of south latitude 29 deg. fresh subterranean water may generally be found. Hand percussion boring plants are used to find water, whether fresh or salt. Boring costs 5*s.* to 6*s.* per foot, including transport charges, and men's time travelling. Wells are sunk along roads and stock routes, and provided with windmill equipment, when they supply small town sites. In areas where fresh subterranean water is found, towns and mines are supplied from groups of wells by pumping. The towns are reticulated and the house services are metered. Charges for water range from 3*s.* to 7*s.* 6*d.* per 1,000 gallons for salt water, and 4*s.* to 7*s.* 6*d.* for fresh water.

Catchment Areas.—Over the Central, and part of the Eucla, division, from about south latitude 29 deg. to the Southern Ocean, the subterranean water is salt. Fresh water is obtained by conservation of rain water.

Distributed over the granitic portions of these divisions are large granite outcrops, ranging in area up to 300 acres, and in altitude to 150 ft. above the surrounding plain. These rocks form excellent catchments for tanks. Masonry-in-cement drains are built round the rocks, and the run-off intercepted by these drains is led by carrier races to the reservoirs. Of the first inch of rain falling on rock catchments 95 per cent. has been impounded, and from rains following 100 per cent. Catchments other than rock generally consist of gently sloping country, with surface of clayey loam, granitic sand, with stony patches, &c., the whole more or less covered with timber and scrub. The natural vegetation on catchments is preserved, as its destruction would result in the discharged water becoming salt. The yield of each rainfall depends on the intensity of the fall on each acre of catchment, the duration of the fall, the length of dry period before the rain, and whether it falls during the hot or the cool season. The yield from a catchment area may be greatly increased by making a network of furrows, or small drains, to lead the water quickly into the main channels. Money is well spent on such work.

Reservoirs, known locally as tanks and dams, are divided into six classes:—

(*a*) Excavated tanks in watertight ground;
(*b*) Tanks made to hold water above the natural surface of the ground;
(*c*) Excavated tanks, clay-pug lined;
(*d*) Concrete-lined excavated tanks;
(*e*) Asphalt-lined tanks;
(*f*) Iron tanks with artificial catchments.

The method of construction of these various tanks is described in detail in the paper and illustrated by examples.

Roofed Reservoirs.—In building reservoirs or tanks in a dry climate an allowance should be made for evaporation in reckoning the capacity, or evaporation should be prevented. It has been proved in the Central division that roofing pays better than adding to the capacity. Tables attached to the paper show the evaporation outside the reservoir at Menzies during 1910 to have been 151.93 in., and the loss by evaporation from the covered tank as $2\frac{1}{2}$ in. The water saved paid for the roof in a short period.

The paper concludes with descriptions of the water supplies in five of the principal towns in the interior. The capital costs range from 22,000*l.* to 53,000*l.* Generally these works provide salt water from wells and fresh water (conserved) for mines and towns. In most cases the two kinds of water are pumped through the same pipes, and in other cases three waters are similarly delivered. The power used is from either gas or Diesel engines—the fuel in the former case being producer-gas made from charcoal and latterly from wood.

CATALOGUES.

Metal Filament Lamps.—From the Osram-Robertson Lamp Works, of Brook-green, Hammersmith, London, S.W., we have received a price list, in a striking coloured cover, of metallic filament lamps of all kinds. With the exception of some of the smaller sizes of half-watt lamps, all these are British throughout, both as regards material, labour and capital.

Electrical Apparatus.—The British Westinghouse Electric and Manufacturing Company, Limited, of Trafford Park, Manchester, have sent us a great budget of leaflets, concerning a wide variety of electrical manufactures. They cover a field from domestic flat-irons and socket adaptors to high-tension isolating switches and "lighting units" for coal mines. The lists are of the Westinghouse Company's standard pattern and arranged for binding in their special folders.

Bending Machines.—A catalogue devoted entirely to machines for bending rods and pipes has been sent to us by Mr. O. N. Beck, of 11, Queen Victoria-street, London, E.C., who represents the Wallace Supplies Company, of Chicago. These machines are of the same general form as the familiar pipe-bender, but have been elaborated so as to have a more general utility. They are capable of bending up to 1 in. round stock, cold, and can be fitted with a variety of stops to form the more complicated shapes.

Technical Literature.—A little folder issued by the McGraw-Hill Boot Company, of 239, West 39th-street, New York, U.S.A., gives brief particulars of the "Power Plant Library" which comprises eight volumes covering the following subjects: Practical Mathematics; Power Catechism; Valve Setting; Boilers, Piping and Pumps; Shafting, Belting and Governors; Electrical Catechism; the Steam Turbine and Mechanical Refrigeration. The volumes measure $5\frac{1}{2}$ in. by 8 in. and contain nearly 3,000 pages. The published price is 12 dols.

Water Testing Apparatus.—A simple, yet ingenious little device for indicating the saltness of feed water on steamers has been brought out by Messrs. Bromel Patents Company, Limited, of 12, Bath-street, Liverpool. It evidently depends, for its action, on the electrical conductivity of water in accordance with the degree of its contamination with mineral salts, and where the only likely source of contamination is sea water, should perform its functions. It is possible, however, that the electrolytic generation of chlorine might, in some circumstances, prove a drawback to its use.

Electrical Instrument Transformers.—A very complete price list of transformers, for use in connection with switchboard instruments, has recently been issued by the British Thomson-Houston Company, Limited, of Rugby. In it there are described and illustrated both current and potential transformers, of the air and oil-insulated types, for dealing with currents of up to 3,000 amperes and pressures of 11,000 volts. They are so designed that they are not affected by stray magnetic fields, and do not disturb the accuracy of neighbouring instruments. A special feature is the use of a copper lining to the porcelain insulating tubes of the air-insulated patterns, which prevents any corona effect or silent discharge that might give rise to acid action and thus destroy the insulation.

THE METRIC SYSTEM.

TO THE EDITOR OF ENGINEERING.

SIR,—If our trade has suffered by foreign buyers not understanding our weights and measures, surely that matter might be largely remedied by each manufacturer when he brings out the next edition of his catalogue. An afternoon spent with a metric table and a slide rule would suffice to add the metric equivalents to all the figures given. It would not be necessary to go far into decimals. For most purposes whole numbers of millimetres would suffice, as the error would not exceed $\frac{1}{50}$ in. at the worst. For instance, a 6-in. lathe would find its equivalent in 153 mm. Actually 153 mm. equal $6\frac{1}{32}$ in., but does any maker guarantee the height of his lathe centre to $\frac{1}{32}$ in., and does any buyer measure it with a more accurate standard than a rule, either inch or centimetre? Many of the dimensions that appear in catalogues, such as overall lengths and widths, are not correct within $\frac{1}{4}$ in., so they would offer no difficulty. As for what may be called internal dimensions, they do not interest the buyer one atom.

Weights of machinery are always approximate, and offer no difficulty whatever. Currency is another matter, because it is complicated by rates of exchange. I do not see how a seller can quote prices in foreign currency except with a time limit.

Yours truly,
"COMMERCIAL."

TO THE EDITOR OF ENGINEERING.

SIR,—Mr. Allcock, in his lecture on the above at the Institution of Civil Engineers, touched upon the advantages to be expected to British export trade with foreign countries if this system were adopted.

The presumption here is, that we are now disadvantaged. Is this so?

In the interval between the Boer War and the beginning of the present trouble, during which time the British Empire remained of the same extent, British exports to foreign countries and to British possessions and dependencies have increased considerably, but to foreign countries—having diverse systems—to a greater degree, viz., 60 per cent., than to British possessions, which show 54 per cent. increase only.

These results are exclusive of re-exports.

Yours truly,
W. H. THORPE.

60, Winsham-grove, Clapham Common, S.W.,
March 28, 1917.

TO THE EDITOR OF ENGINEERING.

SIR,—Why, oh why, indeed, did Nature let us develop ten fingers and ten toes—or, rather, perhaps, why did not Nature atrophy two of each, and so have saved us from a cause of endless trouble and squabbling? The ten-finger system is the basis of the decimal and metric systems—other so-called bases are merely developments of the prime fact or idea. Well, we all know this—just so. So much easier, then, to apply the knife and scratch out the past and start again.

Now is the time. There never was its like before, and there probably never will be. It is the effect of German commercial ramifications that has caused the cry for a universal metric system. It is not so certain that it is even a metric system primarily, but merely some universal system. With the whole world practically now at war with Germany, and going to beat her, let us throw the thing overboard, lock, stock and barrel, and start again with an arithmetical scale of notation 8 instead of 10. Whatever we do will give us stomach-ache for a while, and it is a question whether it will be worse with one than another change. But we do want badly to be able to chop things in halves, halves, halves *ad infinitum*; and, after all, this is the root of the metric trouble, or, rather, decimal, which is the father of the metric.

Personally, I can use the metric system as well as anyone, but I am always up against the radical nuisance in it, not the units themselves. The fact stares us in the face and we blush—and in effect change the subject.

Most of us will be dead in 50 years' time (I should say 62), so our own short-lived trouble is of little moment. It is just as easy to teach our children 8 notation as 10, and let us leave them a useful legacy—and the recreation of translating classic engineering literature, classic lingual translation being practically exhausted. Do not let the present generation puff themselves with the idea that the vast stock of technical (there is no other worth speaking of, the whole quagmire of civilisation being technical) data presents insuperable difficulties. It does not. The quantity of really fundamental data is trivial, can be translated within a week, and probably be confined within the covers of a very small pocket-book indeed. The bulk of our data of to-day will be obsolete in much less than 50 (62) years' time, just as that of a few years ago is obsolete now. Your pages of 20 (24) years ago are obsolete in the technical sense, and we only refer to them on occasion for a quotation, just as we refer to Cæsar or Plato for a quotation.

I repeat, *now* is the time for a universal change of *notation*, and the general emancipation from a decimal system of weights and measures, and all other more or less grotesque systems of division based on casual conveniences. But most certainly now is *not* the time to play up to Germany and adopt the system she has appropriated in her pre-war rush. A gestation period of 10 (12) years to 20 (24) years might be given, in which all the signatory nations (which would at the present juncture naturally include all except the Central Empires, but the Central Empires compulsorily at the termination of the war) would be obliged to give old and new notations side by side to suit the particular sphere of operation, in order to provide the necessary education, prevent mistakes and more or less wilful manipulations.

Some may take this as "humorous," others as serious, others as an emanation from a lunatic. I am sure I do not mind which, but I certainly do not wish to see the metric system as it stands foisted upon us, as in itself it is no better than any other system, and in many respects much worse.

Yours truly,
Birmingham, April 11, 1917. A. JUDE.

TO THE EDITOR OF ENGINEERING.

SIR,—Before any headway can be made with the metric system in England, the general public must be educated to understand it; if a person requires a kilo. of potatoes, a metre of steel or a litre of milk, and has no idea what these quantities represent, the quantities have no meaning to that individual.

The metric system has been taught in the schools and evening institutes for many years, but as metric sizes are so seldom met with in everyday life, little interest is taken in them by the average student, and the tables are promptly forgotten. The electrical and petrol motor industries have helped to familiarise many with metric sizes, and the use of these standards in scientific work is steadily helping, but before any great progress can be made, metric sizes must be worked to a much greater extent than has hitherto been the case; of course in many cases it involves slightly greater expense, but the Government and public bodies could do a great deal in the matter. In a country like England, where manufacturing by our own standards has been in progress for 150 years and all machines and tools made to those standards, progress must necessarily be slow, especially as the conversions from English to metric and *vice versa* are cumbrous. Fortunately in screw-cutting it is very easy to convert to metric threads on an English lathe, provided a "translating" wheel of 127 teeth is provided, this being based on the fact that 1 inch = 25.4 mm. and $\frac{25.4 \times 10}{2} = 127$.

Many people are not conversant with decimals, while the displacement of the decimal point, which is often done, has a serious effect upon the result.

The fact that the English foot is such a convenient measure and is so easy to subdivide must undoubtedly make it a strong rival to the metric system in England, while neither the metre or millimetre is a convenient measure for many purposes, and this must largely militate against their general adoption here.

Even if the metric sizes do not become general here we must see to it that they are used for trading with those countries where this system has been adopted.

Where the metric sizes are used, the great advantages of the decimal notation are neutralised by the fact that many sizes are used which are not decimal multiples or sub-multiples, *e.g.*, the 75-mm. gun, the 4.2-cm. howitzer, our own British Association screw threads, &c. The centesimal division of the circle is another instance of the breakdown of the decimal notation. While admitting that many English weights and measures are cumbrous, they have some advantages, and even should the metric system be made compulsory it would be many years before it would be generally used and understood, as witness the fact that "pottles" and other old measures are still used in many parts of England at the present day, although the Imperial weights and measures have been compulsory for so many years.

One great advantage, if the metric system became universal, would be that there would only be the one system of weights and measures to be taught and learnt, instead of the multiplicity at present in use.

Yours truly,
C. T. SUTTON.

62, Arnott-road, East Dulwich, S.E. 15, April 6, 1917.

THE OPTOPHONE.

TO THE EDITOR OF ENGINEERING.

SIR,—A report of my lecture on "Selenium and the Optophone" appears in your issue of February 9, page 133. Your reporter expresses some doubt as to whether whole words in ordinary type can be read blindfold with the Optophone. This has now been definitely proved to be quite feasible, as you will see from enclosed report. Not only can a newspaper be read with a speed of at least three words a minute, but also, I find, type written documents and even carefully written manuscript.

Yours faithfully,
E. E. FOURNIER D'ALBE.

Selenium Laboratory, 27, Maddox-street,
London, W. 1, April 7, 1917.

THE F.S.S. SYSTEM OF UNITS.

TO THE EDITOR OF ENGINEERING.

SIR,—The foot-pound-second system is not a convenient one for English engineers, who are accustomed to the pound as a unit of force. They require a unit of mass such that a force of 1 lb. will give it an acceleration of 1 foot per second per second; and I beg to suggest that this unit might conveniently and appropriately be termed the *steve*, in honour of our George Stephenson and Robert Stevenson. We should then have an F.S.S. system corresponding exactly to the C.G.S., but without the practical inconvenience of this and the F.P.S.

Yours faithfully,
W. F. DUNTON.

165, Tamworth-road, Newcastle-on-Tyne,
April 6, 1917.

RESEARCH AND THE COTTON INDUSTRY.

AT the end of July of last year, at the instance of the Advisory Council of the Committee of the Privy Council for Scientific and Industrial Research, a meeting of representatives of some of the larger firms engaged in the various branches of the cotton trade, and others interested in textile research, was called by the Lord Mayor of Manchester to consider the possibility of establishing a scheme for the scientific investigation of the various problems presented by the cotton-using industries, and it was agreed that there was great need for research bearing on the cultivation and manufacture of cotton, and in the dyeing, printing, bleaching, and other finishing processes. It was also thought that efforts should be made to increase and to improve the system of textile education. At an adjourned meeting it was decided that some practical steps should be taken to organise a complete scheme for these two purposes. A Provisional Committee was appointed, and this, in due course, was constituted a committee of the Advisory Council of the recently-formed Government Department of Scientific and Industrial Research.

This committee is largely representative of the various interests concerned. Its function is to formulate a preliminary scheme of a comprehensive character and to report to the Advisory Council, and then to lay before the trade, for its consideration, definite proposals for the establishment of a research association, eligible for recognition by the Government Department, and consequently for monetary grants from the National Exchequer.

The Provisional Committee consists at present of the following members: Mr. J. W. McConnol (Fine Cotton Spinners' Association, Limited), chairman; Mr. H. R. Armitage (Bradford Dyers' Association, Limited); Dr. W. Lawrence Balls (late of the Khedivial Agricultural Society of Egypt and the Egyptian Ministry of Agriculture); Messrs. T. D. Barlow (Messrs. Barlow and Jones, Limited), F. W. Barwick (Manchester Chamber of Commerce Testing House), Stanley Bourne (cotton doubler, representing the Nottingham Chamber of Commerce), Lindsay Cropper (Messrs. J. and P. Coats, Limited), Henry P. Greg (Messrs. R. Greg and Co.), J. C. M. Garnett (Manchester School of Technology and the University of Manchester), A. E. Hawley (dyer, representing the Leicester Chamber of Commerce), Forrest Hewit (Calico Printers' Association, Limited), E. L. Hoyle (Messrs. Joshua Hoyle and Sons, Limited), Alfred J. King (Bleachers' Association, Limited), Kenneth Lee (Messrs. Tootal Broadhurst, and Lee Company, Limited), J. H. Lester (late of the Manchester Chamber of Commerce Testing House), James Prestwich (Federation of Master Cotton Spinners' Association), Fred. J. Smith (British Cotton and Wool Dyers' Association, Limited), and Charles H. Turner (Cotton Spinners' and Manufacturers' Association). Mr. Ac. Abbott, H.M. Inspector of Technical Schools, has been appointed by the Advisory Council, with the concurrence of the Board of Education, to act as secretary *pro tem.*

The Provisional Committee are holding fortnightly meetings. They have to consider the place for research in each branch of the cotton industry, whether in the cultivation of cotton, in spinning, doubling, manufacturing, knitting, lace-making, bleaching, dyeing, printing, finishing or in the technology of cellulose. They have also to ascertain what facilities now exist for the education of boys entering any of these branches, and what opportunities are likely to be offered by the trade for the employment of highly trained men. To complete their labours they will have to formulate a scheme both for an institute to undertake research work in collaboration, so far as practicable, with existing bodies, and for an association of firms and individuals willing to make donations and subscribe regularly for a period of years to promote research and improve technical training.

The terms and limitations under which the association can obtain its share of the million pounds granted by the Treasury to promote scientific and industrial research will be ascertained by the Provisional Committee. Any suggestions relating to the researches to be undertaken, or to any other matters coming within the scope of the proposed association, will be welcomed by the committee, and should be sent to the Secretary, Provisional Committee on Cotton Research, 108, Deansgate, Manchester.

THE BESSEMER AND OPEN-HEARTH PROCESSES IN THE UNITED STATES.—The following figures, giving the productions in tons of Bessemer and open-hearth steel in the United States for a number of years, are taken from the *Iron Trade Review*, Cleveland, Ohio:—

Year.	Open-hearth.	Bessemer.
1876	19,187	469,639
1880	100,851	1,074,262
1885	133,376	1,519,430
1890	513,232	3,688,871
1895	1,137,182	4,909,128
1900	3,398,135	6,684,770
1905	8,971,376	10,941,375
1906	10,980,413	12,275,830
1907	11,549,736	11,667,549
1908	7,836,729	6,116,755
1910	16,504,509	9,412,772
1915	23,679,102	8,287,213

These figures show that 1906 was the record year for the production of Bessemer steel. In 1907 the tonnage of open-hearth and Bessemer differed by a very small amount only, and in 1908, in the midst of a serious business depression, the output of open-hearth steel took a lead which has been constantly increasing.

THE STANDARDISATION OF SCREW THREADS; THE WHITWORTH THREAD.

TABLE REFERRED TO IN QUESTION 6 (FOR DRAWINGS OF THE THREADS, SEE FIGS. 1, 2 AND 3).

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.
	Depth of Thread.		Full Diameter.						Effective Diameter.						Core Diameter.					
			Male.			Female.			Male.			Female.			Male.			Female.		
Diameter of B.S.F. Screw.	Present Standard.	Suggested Modification.	Present.	Suggested Modification.	Tolerance (Minus).	Present.	Suggested Modification.	Tolerance (Plus).	Present.	Suggested Modification.	Tolerance (Minus).	Present.	Suggested Modification.	Tolerance (Plus).	Present.	Suggested Modification.	Tolerance (Minus)	Present.	Suggested Modification.	Tolerance (Plus).
in.	in.	in.	(Maximum.) in.	(Maximum.) in.		(Minimum.) in.	(Minimum.) in.		(Maximum.) in.	(Maximum.) in.		(Minimum.) in.	Minmum.) in.		(Maximum.) in.	(Maximum.) in.		(Minimum.) in.	(Minimum.) in.	
¼	0.02465		0.2500			0.2505			0.2254			0.2259			0.2007			0.2012		
⅜	0.05335		0.7500			0.7509			0.6966			0.6975			0.6433			0.6442		
1½	0.08005		1.5000			1.5012			1.4200			1.4212			1.3399			1.3411		

THE STANDARDISATION OF SCREW THREADS.

THE Screw Thread Committee of the Engineering Standards Committee have for some time past been devoting considerable attention to the manufacturing difficulties which arise in connection with the production and gauging of thoroughly interchangeable screw threads, particularly of the Whitworth form, and as a result they are now issuing to engineers and gauge makers a series of queries which deserve earnest attention. These queries are accompanied by a letter, which we reproduce below :—

Whitworth Form of Thread.

DEAR SIRS,—The Engineering Standards Committee, with the active co-operation of the Ministry of Munitions, are making an investigation with a view of seeing whether the manufacture and gauging of interchangeable screw threads of Whitworth form could be facilitated by some modification being made to the form of the thread.

It has been submitted to the Committee that the difficulty experienced in the production of truly interchangeable screw threads of Whitworth form is largely owing to the fact that a fit has to be obtained on all the five elements of the screw, namely, the angle, the full, core and effective diameters and the pitch, and that by suitable modifications to the form of thread the necessity of close adherence to some of these dimensions could be avoided, with consequent increase in the rate of production and gauging of the finished product.

For the purpose of obtaining the views of manufacturers and gauge makers as to whether any modifications in the form of thread are desirable, and the directions in which such modifications (if any) may most conveniently be made, the Sub-Committee on Screw Threads, with the assistance of the official representatives of the Ministry of Munitions, have drawn up a list of questions, C.L.(M.) 3413, two copies of which are enclosed herewith.

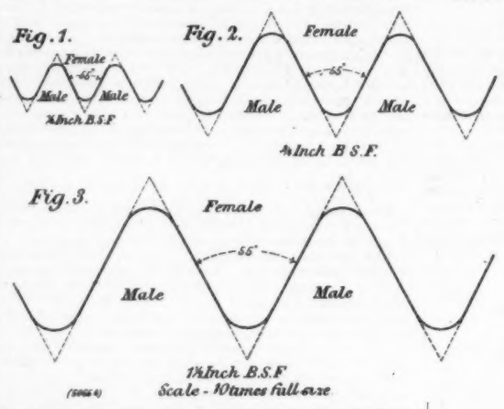
The committee trust that you will assist them in this important investigation by completing one of the forms (retaining the other for reference) and returning it to me at your earliest convenience, in order that they may be able, with the least possible delay, to come to a conclusion upon a subject which you will agree is of vital importance to the engineering interests of this country.

I am, dear sirs, yours faithfully,
C. LE MAISTRE,
Secretary.

28, Victoria-street, Westminster, London, S.W.,
April, 1917.

We reproduce herewith the series of questions referred to in the above letter, and also the table and diagrams by which the questions are accompanied. With regard to the diagrams, we may say that as circulated by the Engineering Standards Committee, Figs. 1, 2 and 3 are drawn twenty times, and Figs. 4 and 5 fifty times full size, this great enlargement much facilitating the filling in of any suggested modifications of the threads. Of course our space would not permit of our reproducing the diagrams to these large scales, and our engravings, which must be regarded as indicating the character of the originals, are all drawn to the scale of ten times full size.

In connection with this matter we may direct special attention to two articles recently contributed to our columns by Dr. W. C. Unwin, namely, one entitled "A Suggested Modification of the Whitworth Screw Thread," which will be found on page 158 of our issue of February 16th last, and the other entitled "Further Notes on Screw Threads," which appeared on page 289 of our issue of March 30th. In these communications Dr. Unwin explains very clearly the difficulties which attend the production and gauging of the Whitworth form of thread, and makes valuable suggestions which certainly deserve the most serious attention of all engineers at the present time. We append the



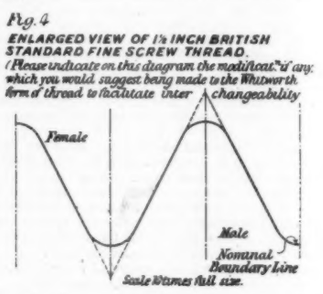


Fig. 4
ENLARGED VIEW OF 1½ INCH BRITISH STANDARD FINE SCREW THREAD.
(Please indicate on this diagram the modification, if any, which you would suggest being made to the Whitworth form of thread to facilitate interchangeability
Female
Male
Nominal Boundary Line
Scale 10times full size.

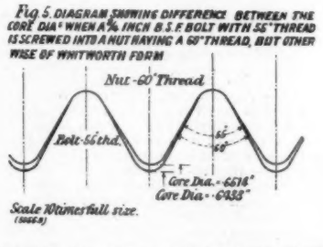


Fig 5. DIAGRAM SHOWING DIFFERENCE BETWEEN THE CORE DIA" WHEN A ¾" INCH B.S.F BOLT WITH 55° THREAD IS SCREWED INTO A NUT HAVING A 60° THREAD, BUT OTHERWISE OF WHITWORTH FORM
Nut -60° Thread
Bolt-55° thd.
55°
60°
Core Dia.-.6518"
Core Dia - .6335"
Scale 10times full size.

questions, diagrams, &c., to which we have referred above.

Standardisation of Screw Threads.

The following questions have been prepared for the purpose of obtaining the views of manufacturers of screws of all types as to the most suitable form of thread that should be standardised for all classes of engineering work :—

QUESTIONS.

1. Are you in favour of making any alteration in the present form of Whitworth thread ?

2. In the event of your replying to question 1 in the affirmative, do you consider it essential that screw threads cut to the revised form should be interchangeable with existing work ?

3. Do you consider that :

(*a*) Screws should be made a good fit on the slopes of the threads ?
(*b*) Screws should also fit closely at crests and roots ?
or (*c*) Clearance should be allowed at crests and roots ?

4. Assuming clearance to be given at crests and roots, do you suggest that clearance should be given wholly in the female thread, or partly in the male and partly in the female thread ?

5. Should you recommend any departure from the present form of crest and root for male and female screws, please indicate the same on Fig. 4, stating your reasons as fully as possible, bearing in mind :—

(*a*) The strength of the screw.*
(*b*) Maintenance of a tight fit between bolt and nut under vibration.
(*c*) Ease of production under ordinary workshop conditions.
(*d*) Whether tools will produce the correct form of thread for a reasonable time before undue wear has taken place.
(*e*) Whether the form of thread can readily be checked by suitable gauges.

6. Please indicate on the drawings of ¼-in., ⅜-in. and 1½-in. Whitworth threads, Figs. 1, 2 and 3, and on the attached table, the amount of clearance at crest and root that you would allow between the male and female screws, giving exact dimensions, and the tolerance that you would allow on these dimensions, and also on the effective diameter, having regard to possible wear of taps and dies.

7. What are your views as to the advisability of altering the existing angles of Whitworth and British Association screw threads to 60 deg. as a step towards securing interchangeability with the Sellers and the International Standard screw threads.

NOTE.—Fig. 5 shows the difference between the core diameters when a ¾-in. bolt with a 55 deg. thread is screwed into a nut with a 60 deg. thread and the threads touch at the crests of the bolt.

8. In the event of any change in the form of thread being decided on, state your views as to the inconvenience and expense that may be involved during a transitional period, under the following circumstances :—

(*a*) If no change is made in the angle of the thread.
(*b*) If the angle is changed.

We may add that any firm of engineers interested in the production of screw threads which has not received the documents above referred to can obtain them on application to the secretary of the Engineering Standards Committee, at 28, Victoria-street, Westminster, London, S.W. 1.

* The committee desire to call attention to the fact that by machining out the core diameter of the nuts clearance may be obtained at the root of the threads on the bolts without reducing their strength.

IRON AND STEEL INSTITUTE.—The annual meeting of the Institute will be held at the Institution of Civil Engineers on Thursday and Friday, May 3 and 4, commencing on Thursday at 10.30 a.m. and on Friday at 10 a.m. On the Thursday the Council will present their report for the year 1916; the president will move the adoption of the proposed new by-law for the expulsion of members, as amended at the autumn meeting, for incorporation in the by-laws of the Institute; and the Bessemer Medal for 1917 is to be awarded to Mr. Andrew Lamberton, vice-president. The following papers are expected to be read and discussed :—1. L. Grenet (Firminy, France): "The Penetration of the Hardening Effect in Chromium and Copper Steels." 2. J. N. Kilby (Sheffield): "Steel Ingot Defects." 3. F. C. Langenberg (Harvard, U.S.A.): "Cementation by Gas Under Pressure." 4. G. P. Raidabaugh (Sparrow's Point, U.S.A.): "Origin and Development of the Railway Rail." (Being an historical note communicated by the courtesy of the Ebbw Vale Company.) 5. N. Tschischewsky (Tomsk, Russia): "Case-Hardening of Iron by Boron." 6. N. Tschischewsky and N. Schulgin (Tomsk, Russia): "Determination of the line S.E. in the Iron-Carbon Diagram by Etching Sections at High Temperatures in Vacuo." 7. F. C. Thompson (Sheffield): "Influence of Surface Tension on the Properties of Metals, especially of Iron and Steel."

LAUNCHING SHIPS.*

By PERCY A. HILLHOUSE, B.Sc., Member of Council, and WILLIAM H. RIDDLESWORTH, M.Sc., M.Eng.

SEVERAL papers have already been submitted to this Institution on the subject of the launching of ships. The first was a general non-mathematical essay by the late Mr. John W. Shepherd. It was read in the year 1877, and contained a statement that the object of cambering the launching ways was to avoid the possibility of their becoming hollow should there be an accidental subsidence of the ground. The effect of camber upon pressures and moments was apparently not realised. Mr. Samuda's paper in the same year gave data in connection with the launching of large vessels, the "large vessel" of that date being a battleship of 285 ft. in length and 7,400 tons displacement. In 1882 Mr. Denny gave a very interesting paper on launching velocities, with data for many vessels built by his firm. Mr. Luke in 1907 gave much useful information regarding the launching of the Cunard liner Lusitania, and drew attention to the advisability of estimating the pressure existing between the hull and the after end of the ways. In 1909 and 1913 we had valuable mathematical papers by Mr. John Smith and Mr. A. Hiley dealing in a more or less approximate manner with the effects of declivity and camber.

Of matter published elsewhere than in our Transactions, I would like to draw attention to the very complete account of the launch of the Mauretania, which appeared in *The Shipbuilder*, vol. i, No. 4. The velocity and acceleration of the vessel are traced from her first movement until she was finally brought to rest by the drags. Mr. H. R. Champness in 1899 described the launch of the battleship Ocean to the Institution of Mechanical Engineers. The Journal of the United States Naval Institute for December, 1912, contains an account of a rocking fore poppet in the launching arrangement for the American battleship New York. The object of the rocker was to ensure that the pressure on the fore poppet would be properly distributed throughout its length, instead of all coming upon its fore edge, as is theoretically the case with the usual form of cradle forward.

The present paper describes a method of calculating launching pressures and moments, which, though not so simple as that put forward by Mr. Smith, takes accurate account of the effects of tide, declivity and camber, a form of fore poppet which has been developed and successfully used at Fairfield, and some model experiments made to determine the actual motion of a vessel during the whole process of launching.

Method of Calculation.—Approximate methods for calculating the hydrostatical elements of a ship during launch form the subject of portions of some of the papers already quoted. Having had occasion to investigate a launching problem admitting of many variations under circumstances which made it imperative that the number of approximations used should be as small as possible, the following routine method was devised :—

1. A series of curves of displacement and longitudinal position of centre of buoyancy was drawn for ranges of draught and trim exceeding those likely to occur during the whole launching process. Twenty-five displacement and centre of buoyancy calculations, cross-faired in both directions, were sufficient to allow of these items being plotted on a base of draught at A.P. for each foot of trim through the required range (Fig. 1, below).

2. For each change in one of the many variables a launching calculation sheet (see below) was then filled in, headed by a diagram setting forth the initial circumstances.

3. The results obtained in 2 were then plotted on a base of travel, in order to obtain the travel at which the stern rises, load on fore poppet, minimum moment against tipping, and maximum pressure on after end of ways A.E.W. (Fig. 4).

4. Cross curves were then plotted showing the effect of change in any one variable, *e.g.*, Fig. 2 shows the effect of varying tide, whilst Fig. 2a shows the effect of varying camber for one particular set of circumstances.

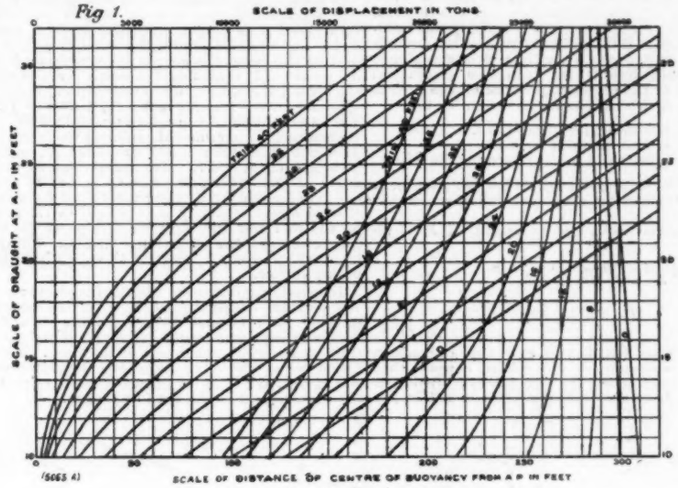
The sheet is designed to facilitate the calculation in a systematic manner of the draught at A.P. and the trim corresponding to any given travel, the recording of the displacement and position of centre of buoyancy under these circumstances, and, finally, the estimation of the required loads and moments. The diagram at the head of the sheet contains all the essential dimensions in the lay-out of the launching ways. The number of dimensions required for this purpose is very limited, being—

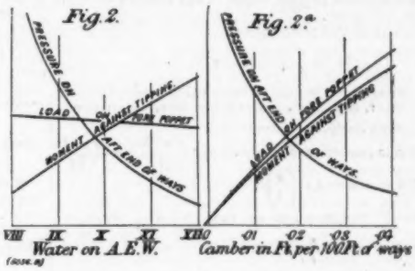
Two declivities (total rise ÷ total length), viz. —

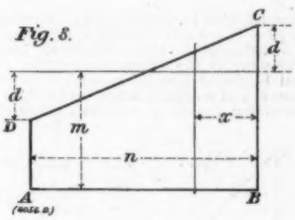
Keel	k
Chord of ground-ways	w
Three heights, viz.—	
Keel at A.P.	K
Top of ground-ways at A.E.W.	W
Tide line	T
Five lengths, viz.—	
Ship	L
Overhang forward of fore poppet ...	O
Sliding ways between poppets	λ
Standing-ways	l
Extension of standing-ways beyond A.P.	E
One camber, viz.—	
On whole length of standing-ways ...	c

Two points may now be emphasised—

(i) The declivity of the ship and of the ways is so

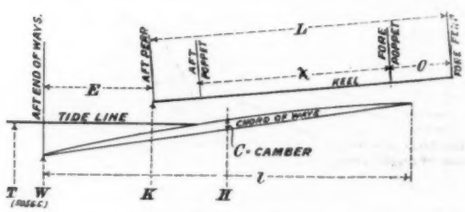




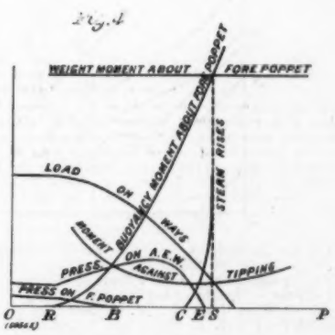


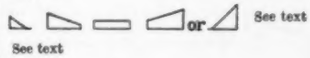
LAUNCH CALCULATIONS.

No. Name. Date.



k = declivity of keel
w = declivity of ways
Δ = Launch weight
g = A.P. to C.G. of ship
Draught forward
Draught aft
Moment of weight about fore poppet = $\Delta (L - O - g)$



	Travel.	o.	—	t.	—	—	—	—
1	A.P. from ½ L of ways	$\frac{1}{2}l - E = x_o$		$x_o + t = x$				
2	Fall in above distance	$x_o w$		$x w$				
3	Round down in above distance	$4c\left(\frac{x}{l}\right)^2$		$4c\left(\frac{x}{l}\right)^2$				
4	Total fall in above distance	$2_o + 3_o$		$2 + 3$				
5	Height of ways at A.P.	$H - 4_o$		$H - 4$				
6	Height of keel at A.P.	K		$H - 4 + K - (H - 4_o) = K + 4_o - 4$				
7	Draught at A.P.	$T - K$		$T - 6$				
8	Change of trim	$8\frac{cL}{l^2}t$						
9	Trim	Lk		$Lk + 8$				
10	Displacement			From displacement diagram for 7 and 9				
11	Load on ways			$\Delta - 10$				
12	Centre of buoyancy from A.P.			From displacement diagram for 7 and 9				
13	Centre of buoyancy from A.E.W.			$12 + E - t$				
14	Buoyancy moment against tipping			10×13				
15	Weight moment causing tipping			$\Delta(t - E - g)$. Note sign + or −				
16	Total moment against tipping			$14 - 15$				
17	Centre of pressure from A.E.W.			$16 \div 11$.				
18	A.E.W. to fore poppet			See text				
19	Pressure distribution			 See text				
20	Pressure per foot length, mean			See text				
21	,, ,, ,, maximum			,,				
22	,, ,, ,, minimum			,,				
23	Pressure per square foot at A.E.W.			L − 0 − 12				
24	Centre of buoyancy from fore poppet			24×10				
25	Buoyancy moment about fore poppet							

* Paper read before the Institution of Naval Architects, March 29, 1915.

small (about 1 in 20, or say 3 deg.) that changes in height may be estimated along a perpendicular to the chord of the ways and applied as if they were vertical, without appreciable error.

(ii) Whilst recognising that the sliding surface is necessarily circular, slope and round down may be estimated as if the curve were a parabola passing through the ends and mid-point of the standing-ways.

These approximations are, more or less, equivalent to assuming that cos 3 deg. = 1, when it actually is 0.9986. The possible accuracy of launch calculations in general is far below the grade of this approximation.

The most convenient point on the standing-ways from which to reckon distances along and perpendicular to the ways is the highest point of the camber or mid-length of the ways.

The height of this point is—

$$W + \frac{l}{2} w + c, \text{ say} = H.$$

To determine the height of the sliding surface at any point, distant, say, x abaft the mid-point, we have—

Fall due to declivity $= x\,w$

Reduction in camber or round down $= c\left(\frac{x}{\frac{1}{2}l}\right)^2 = 4\,c\left(\frac{x}{l}\right)^2$.

Total fall $= x\,w + 4\,c\left(\frac{x}{l}\right)^2$.

Height of sliding-ways at the specified point $=$

$$H - x\,w - 4\,c\left(\frac{x}{l}\right)^2.$$

The initial distance of A.P. from the mid-point of the ways $= \frac{1}{2}l - E$.

Line 1 can now be filled in, entering $\frac{1}{2}l - E$ under zero travel and $\frac{1}{2}l - E + t$ under travel t, &c.; and lines 2, 3 and 4 in virtue of the above relations. Line 5 gives height of ways at the successive positions of A.P. The initial height of keel K is entered under zero travel in line 6, and as the distance between keel at A.P. and the sliding surface is constant so long as the ways are in contact over the whole overlapping length, line 6 can be completed by adding to line 5 this constant difference. Line 7 draft at A.P. is merely (height of tide − height of keel at A.P.)

Having obtained draft at A.P. we now turn to trim. The initial trim is L k, which can be entered under column zero travel in line 9. The change of angle for any travel $t = 8\,c\frac{t}{l^2}$, and the corresponding change of trim $= 8\,c\frac{t}{l^2}$L. This enables us to fill in lines 8 and 9.

The displacement diagram is now referred to, and the displacement and position of centre of buoyancy read off; these are now entered in lines 10 and 12. Line 11 is obtained by the subtraction of the displacements in line 10 from the weight of the ship at launch. A.P., being initially E before A.E.W., at travel t is $t - E$ beyond, and as line 12 gives position of C.B. before A.P., line 13 can be filled in by making the necessary subtraction. Line 14: Moment of buoyancy against tipping is the clockwise moment of buoyancy about A.E.W., and is the product of lines 10 and 13. Line 15: Moment of weight causing tipping is similarly the anti-clockwise moment of the weight about A.E.W; if g is the distance of C.G. of ship forward of A.P., the initial position of C.G. is E + g before A.E.W. (C.G. of course passes A.E.W. when travel = E − g.) Distance of C.G. from A.E.W. at travel t is $t - E - g$, and moment of weight causing tipping is weight × $(t - E - g)$, which will be negative until C.G. passes aft end of ways, and positive afterwards. The total moment against tipping (line 16) is obtained by subtracting the figures in line 15 from those in line 14. The moment against tipping being balanced by the reaction of the standing-ways, and the total pressure or load on the standing-ways being given by line 11, we find the distance of the centre of pressure of load on ways from A.E.W. by dividing the figures of line 16 by the corresponding ones of line 11.

Line 18: Amount of overlap of sliding-ways and standing-ways is obtained as follows:—

Initial distance A.E.W. to fore poppet = E + L − O,
Distance at travel t = E + L − O − t,
If not greater than length of sliding-ways this is the amount of overlap, otherwise amount of overlap is λ.

We have now to consider the pressure between standing-ways and sliding-ways as regards distribution. Line 11 contains full details of the amount of this pressure, on the assumption that the ship moves as if completely constrained by the ways, which is true up to the travel at which the stern rises, of which more anon. We know then the amount of load, the position of its centre of gravity, and the length and position of the overlapping portions of the ways carrying the load. In order to find the intensity of the pressure at any point we must make some assumption about the distribution. The assumption which lends itself most readily to calculation is that of a linear variation, and this will be adopted in what follows; although there is no intrinsic reason why it should be the one most nearly representing the truth—there are indeed some very good reasons for doubting the truth of this assumption. Let the area A B C D (Fig. 3) represent the amount of a load distributed over a length A B in accordance with the straight line C D; call this trapezoidal distribution. Let the centre of pressure on the surface represented by A B be at a distance x from B, then—

where m the mean pressure = P/n,
P = total pressure or load,
n = length of surface carrying the load.

Now let d be the amount by which the maximum and minimum intensities exceed or fall short of the mean.

Taking moments about the mid-point of A B we have—

$$\tfrac{1}{2}\frac{n}{2}d \times \tfrac{2}{3}n = m\,n\left(\frac{n}{2} - x\right)$$

whence

$$d = 3\,m\,\frac{n - 2x}{n}$$

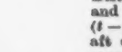
It may be pointed out that with the type of pressure distribution here assumed it not seldom happens that the mean pressure on the ways is considerably departed from at the ends of the sliding-ways even before the ship begins to move; and it certainly is true that when the last operation prior to the actual launch is the cutting away or removal of keel blocks forward or aft, the pressures at the ends greatly exceed those calculated by such means as those indicated above, whilst of course at some other portion of the ways the pressure is correspondingly reduced. The figures of lines 17 and 18 require a little examination before proceeding further. If the centre of pressure falls exactly half-way along the overlap the pressure intensity is uniform, if it falls exactly one-third the length along the overlap the pressure varies from zero at one end to twice the mean at the other, if within the middle third the pressure distribution is such as A B C D (Fig. 3). If the centre of pressure falls outside the middle third the reasonable assumption is that the curve of distribution is a straight line forming a triangle with the axis and the vertical at one end of the length in contact. This avoids the supposition that tension exists between the sliding surfaces.

A graphic method of determining these points is mentioned later and may be used with advantage.

Line 19 can now be filled in with a series of small diagrams of the pressure distribution as—

indicating pressure part way along overlap and greatest at A.E.W.

indicating pressure along all overlap and greatest at A.E.W.


indicating pressure uniform.

indicating pressure all along overlap and greatest at fore poppet.

indicating pressure part way along overlap and greatest at fore poppet.

The formula just established for the departure from the mean pressure in trapezoidal distribution is now applied to the appropriate cases and the maximum and minimum pressures thus determined. When the pressure distribution is of what might be called the triangular type, the procedure is to find the distance of the centre of pressure from the heavily loaded end; multiply this by three, and so obtain the length over which the pressure is distributed, the mean and maximum pressures are then obvious. This completes lines 19, 20, 21 and 22. Line 23 is merely the maximum pressure per foot length of ways at A.E.W. divided by the combined width of the ways.

Line 12 gives distances of centre of buoyancy from A.P.; subtraction of this distance from (length of ship − overhang forward) will give distance of centre of buoyancy from fore poppet, line 24; the product of displacement from line 10 and the distance tabulated in line 24 gives moment of buoyancy about fore poppet, line 25.

It need scarcely be said that constant plotting should be adopted to check and confirm the figures entered up line by line; many errors may in this way be detected at a stage when they can easily be remedied.

The essential curves in the final launch diagram are obtained (1) from line 25, the moment of buoyancy about fore poppet, the intersection of which with a straight line representing the moment of the weight of the ship about fore poppet gives the point in the travel down the ways at which the stern begins to rise—beyond this point the curves under consideration have no value; (2) from line 11, which gives the load on the ways and consequently at the travel indicated above the load on the fore poppets; (3) from line 16, which gives the moment against tipping, the graph of which enables us to determine the minimum value and position at which it occurs; (4) from line 23, giving the pressures on A.E.W.; also from lines 21 and 22 a curve of maximum pressure on the hull of the vessel can be obtained by plotting the actual distribution of the pressure, completely defined in lines 19, 21 and 22, on the hull and drawing the envelope of the series of trapezoids and triangles thus obtained. The pressure intensity becomes infinite (in theory) when the stern begins to rise.

Interesting information about change-over points in the pressure distribution curves can be obtained by plotting lines 17 and 18 and adding straight lines defining the position of the middle point and the middle third of the overlapping part of the ways. Indeed the travel when the stern rises can be determined by this means, as the travel when the centre of pressure on the ways coincides with the fore poppet.

Fig. 5.

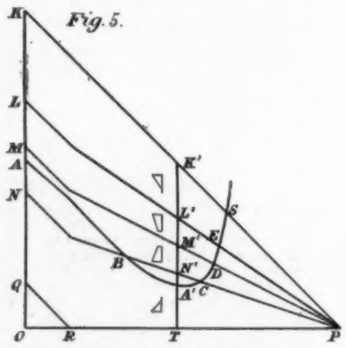
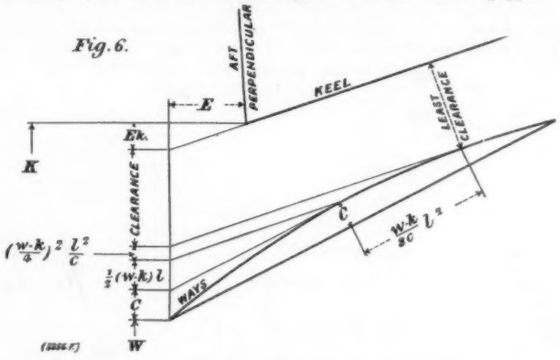


Fig. 6.



In Fig. 5 travel is measured along O P, and at any travel, say O T—

T K′ = amount of overlap of ways,
T L′ and T N′ define the position of the middle third of the overlap,
T M′ gives the position of the centre of the overlap,
T A′ = distance of centre of pressure from A.E.W.

The pressure distribution is as indicated by the small diagrams in the spaces bounded by the straight lines specified above.

At S the stern rises, and if it should happen that the line A B C D E S touches the axis O P, the minimum moment against tipping is zero. Whilst if it crosses, there is an actual tipping moment.

If the special displacement centre of the buoyancy diagram already mentioned has a range which includes the actual launched draught, it can be used to find the water-line at which the ship would float if at rest with the fore poppet on the ways after the stern has risen. Two additional sets of curves are required, viz., (1) a set of curves giving the draught at fore poppet in terms of the draught aft and the trim; (2) a set of curves giving the moment of buoyancy about fore poppet for a sufficient range of trim and of draught. Knowing the draught at fore poppet, which can easily be calculated for any travel on the lines already laid down, and the moment of weight about fore poppet, we can from these two sets of curves pick out the trim which gives the requisite moment, and hence the displacement and load on the fore poppet, which is the difference between this and the weight of ship.

Sometimes an important matter is that of the minimum clearance between the sliding surface and the hull of the ship; the method following is one by which the minimum distance between the lines of keel and of sliding surface and the position of this point of closest approach can be obtained.

The clearance is the distance between the keel and a line parallel thereto touching the sliding surface. The angle between this line and the chord of the ways, or tangent at middle point of length = $w - k$, and the distance along the ways from the middle point corresponding to this change of angle is obtained from—

$$w - k = 8\,c\frac{x}{l^2}.$$

i.e.,

$$x = \frac{(w-k)\,l^2}{8\,c},$$

and the round down or reduction of camber (see page 362, col. 1) is—

$$= 4c\left(\frac{x}{l}\right)^2 = 4c\,\frac{(w-k)^2\,l^4}{64\,c^2\,l^2}$$

$$= \frac{(w-k)^2\,l^2}{16\,c}.$$

The projection lines on the diagram, Fig. 6, indicate the connection of the various dimensions, and the final expression for clearance becomes—

$$\text{Clearance} = K - W - E\,k - c + \frac{w-k}{2}\,l - \left(\frac{w-k}{4}\right)^2\frac{l^2}{c}.$$

The additional clearance due to rise of floor or shape of hull can be readily determined from a vertical section of the ship in line with the inner edge of the ways.

The Fore Poppet.—Theoretically, when the stern of a vessel rises during her launch she is supported partly by the buoyancy of her immersed portion and partly by a single upward force exerted by the ground-ways upon the forward edge of her foremost poppets. As this edge has no area, the intensity of the pressure is theoretically infinite. In practice, due to crushing and consolidation of the materials, the load is distributed over some unknown length of the forward make-up, and the local intensities of pressure thus brought down within limits which can be dealt with. To assist in obtaining this result layers of soft crushable wood packing are sometimes inserted between the poppets and the upper surface of the sliding-ways. It is impossible to determine exactly what length of the make-up is actually called upon to assist in supplying the support required at the fore end of the ship, but if we are to make any working estimate of the strength to be provided, some assumption must be made. In the cases of the largest vessels launched during recent years at Fairfield, we have assumed that the total theoretical load upon the fore poppet would be distributed over a length of about 30 ft. The mean assumed load per foot run of ways was therefore one-thirtieth of the total load, and half of this on each side of the vessel. It was then assumed that the longitudinal distribution of this load could be fairly represented by a portion of a parabola (Fig. 7), the value at the after end of the 30 ft. being equal to the mean load, and that at the fore end twice the mean load. The total load thus to be provided for was 1½ times the theoretical load. The separate poppets included in the 30 ft. were then made strong enough to withstand the load indicated by the portion of the load-curve in way of each, with a factor of safety not less than 3.

Form and Strength of Poppets.—Let S S (Fig. 8) be the transverse section of the vessel's bow in way of any single poppet and P the upward force to be supplied by the ways W. The problem is that of constructing some form of cradle or strut to transmit the force P from W to S. If there would be no tendency for the vessel to capsize when supported only by her buoyancy aft and the fore poppets forward, and if the keel were sufficiently high above the ways, this would be most simply effected by means of a cross beam of steel and/or timber stretching transversely from way to way and supporting the vessel at the middle line as shown in Fig. 9. Cross logs were used in launching H.M.S. Terrible, though in this case the load was not concentrated at the middle of the beam as shown in figure, but distributed more or less evenly on beams and ways by means of diagonal struts and packing, as indicated in Fig. 10.

In most cases, however, it would be found difficult to obtain sufficient strength with wood logs or sufficient "give" with steel beams to ensure a proper longitudinal distribution of the total load over the required distance. The common method is to support each side of the vessel from its own way, and to devise the most convenient and suitable method of strutting apart the two mutually inclined surfaces—the horizontal surface of the way and the more or less sloping surface of the ship's side. Either vertical or inclined struts may be adopted (Fig. 11). Vertical poppets will be longer than inclined ones, and will therefore be capable of a greater amount of crushing and adjustment to assist in distributing the load. But in the case of a vessel with very fine sections forward vertical poppets would either become so long as to be in danger of buckling out sideways, or would not meet the section at all except at an impracticable height. In any case some means must be devised to prevent slipping between the ship's side and the top of the poppet. If a sloping strut be placed normal to the slope of the vessel's side there will be no tendency to slip between poppet and hull, but it will be necessary to tie in the lower end of the poppet to prevent it from sliding outwards across the ways. If the poppet be placed at some angle intermediate between these two limiting positions, ties will be required both at head and heel.

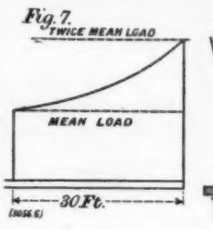


Fig. 7.

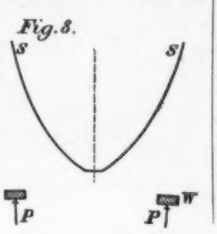


Fig. 8.

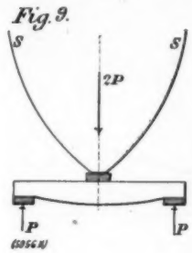


Fig. 9.

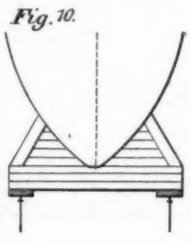


Fig. 10.

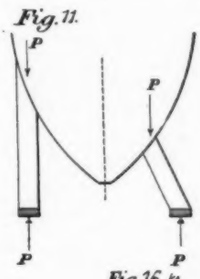


Fig. 11.

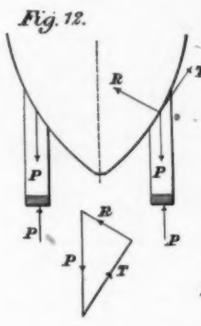


Fig. 12.

Fig. 13.

Fig. 14.

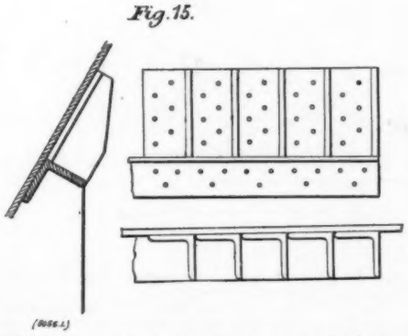


Fig. 15.

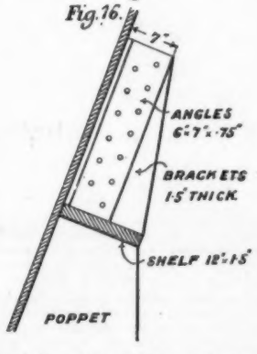


Fig. 16.

When the poppets are vertical their upward thrust P is transmitted to the hull by two components—a normal pressure R and a tangential force T, the triangle of forces being as shown in Fig. 12. There is no transverse compression of the hull, since the inward horizontal component of R is balanced by the outward horizontal component of T. Internal shoring, if found necessary, need therefore be in a vertical direction only. For small vessels resistance to the tangential force T is often obtained solely by fitting the poppets closely against the lower edge of one or more outside strakes, an angle bar being sometimes introduced to increase the bearing surface for the woodwork (Fig. 13).

This method was successfully used in launching R.M.S. Campania, then regarded as a "monster" vessel, though as a precaution the heads of the poppets were also bound by chains passing from side to side under the keel. The launching weight was 9,100 and the total pressure upon the fore poppets about 1,800 tons.

For heavier vessels and large loads on the fore poppet it has become common to obtain resistance to the tangential force by riveting a steel shelf to the shell plating (Fig. 14) The shelf is supported by bracket plates at frequent intervals, and it is not difficult to obtain a sufficiency of rivet connection between shelf and hull. This shelf is often made of considerable breadth and fitted with an outer angle to stiffen its edge between the brackets and to hold in the poppets. The Mauretania rested on two shelves, each 3 ft. 6 in. wide; for the Ocean the shelves were each 6 ft. in width, and covered the whole breadth of the vertical poppets. Such a construction appears to be objectionable, for two reasons. In the first place its under surface is irregular, and will probably have numerous rivet heads projecting from it. This renders it difficult to ensure a good fit between the shelf and poppets, and will therefore tend to produce irregular increase of pressure at some points and to the entire absence of pressure at others. To some extent, of course, this variation will be reduced when the load comes on and the more severely loaded portions of the poppets crush. But it is conceivable that if the fit were not perfect the whole of the load might be concentrated upon the outer edge of the shelf, and so produce considerable strains in the unsupported portions between the brackets, and even buckling of the brackets themselves. For all large vessels launched at Fairfield in recent years—beginning with H.M.S. Commonwealth—we have for this reason used a very narrow shelf, and have supported it as closely as possible by vertical angle bars. The form first used is shown in Fig. 15, and consisted of a longitudinal angle bar, 6 in. by 6 in. by ⅞ in., supported by short lengths of the same scantling placed vertically as close together as possible and fitting closely against the longitudinal bar, though not connected to it. This method makes it easy to obtain the necessary rivet area, the tangential force is very directly transmitted to the rivets, and there is no danger of the flange of the angle bar being bent upwards, even although the whole load should by chance be concentrated on its outer edge.

There still remains, however, the fact that the surface to which the upper ends of the poppets are to be fitted is somewhat irregular. The poppets have to be notched out to fit the angle bar, and holes dug in them to receive the heads of the rivets connecting it to the hull. All this tends towards bad fitting and non-uniformity of loading. In later jobs this difficulty was avoided by replacing the longitudinal angle bar by a stout plate not connected to anything, but merely placed hard against the lower ends of the vertical angles so as to form a smooth surface for the poppet heads (Fig. 16). The supporting angles can be of any required length, placed hard together at the fore end of the make-up, where the load is greatest, and reduced in length and spaced more widely apart as the loads are reduced towards the after end. If the angles are riveted directly to the shell plating, the shelf should, if possible, be kept above the expected water-line, so that they can be removed while the vessel is afloat.

In order to avoid piercing the vessel's hull by the numerous rivet holes involved in the method just described, a "banjo" or "swing" plate is sometimes fitted, passing from the heads of the poppets on one side right under the vessel and up to the poppet heads on the other side. The shelf and its supporting angles can then be connected to the swing plate and the whole structure removed in one piece after the vessel is afloat. This change affects the transmission of the thrust P of the poppets to the hull, as is shown by the triangle of forces in Fig. 17. The pressure R and the tangential force T remain as before, but the latter is now taken up by the swing plate, and its vertical component V is transmitted to the keel. The ship is now supported on each side by X, the vertical component of R acting at the top of the poppets, and by V, the vertical component of T acting as the keel. The horizontal component of R now acts compressively upon the ship's structure, and any internal shoring should be in the direction of R.

If the cross-section of the hull is of rounder form than indicated in the preceding figures it may be necessary to bend the swing plate and introduce additional packing at the change of direction. The vessel is now supported at three points on each side, by the vertical components of R, R′ and T′, and the diagram of forces becomes more complicated, as shown in Fig. 18.

In the limit the swing plate may be, as it were, wrapped round the whole of the section and closely packed, the only straight portions being those in way of the poppets and under the keel. The diagram of forces, Fig. 19, shows P, R and T as before. To find the hull pressure and tension of the swing plate at various points, divide the curved portion of the plate into a number of equal parts, and from the lowest point of the triangle of forces draw radial lines parallel to the mean slope of each (approximately straight) intercept. From the right-hand corner of the triangle drop a perpendicular upon the radial line T^1, and from its foot drop a perpendicular upon the radial T^2, and so

LAUNCHING SHIPS; FORE POPPETS.

Fig. 17.

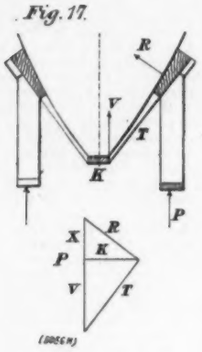
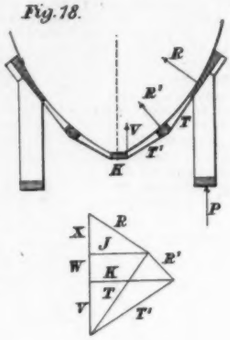


Fig. 18.



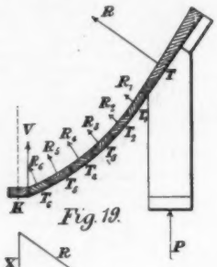


Fig. 19.

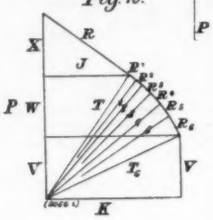


Fig. 20.

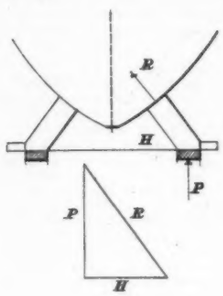


Fig. 21.

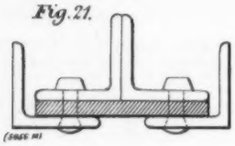
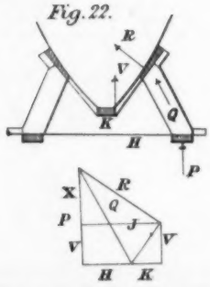


Fig. 22.



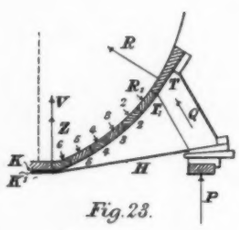


Fig. 23.

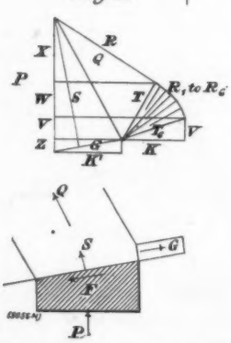


Fig. 24.

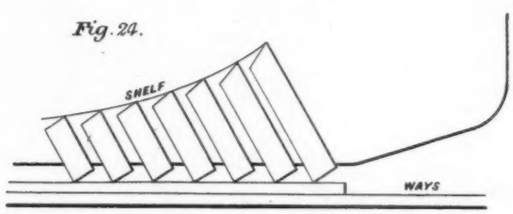
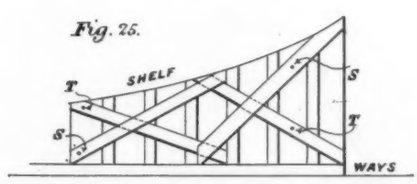


Fig. 25.



on. The lengths so cut off from the radials give the varying values of the tension in the swing plate, while the lengths of the various perpendiculars represent for each portion the total pressure normal to the hull. The total upward force P is then transmitted to the hull in three portions—X, the vertical component of R, W, the total vertical component of all the pressures transmitted for the curved portion of the swing plate, and V, the upward thrust on the keel—and the internal shoring should be arranged to take up these several portions of the total support.

Consider next the case of poppets placed normally to the hull surface, with a cross tie-plate to prevent their lower ends sliding apart. The triangle of forces will be as shown on Fig. 20, and it is at once evident that the normal pressure R upon the hull is much greater than before for any given value of P. The horizontal components of R, each equal to H, will tend to compress the hull transversely. The internal shoring should lie in the direction of R.

To give the lower surface of the poppets a grip on the tie-plate H, a shelf supported by closely spaced angles may be employed, the construction being similar to that already shown for the shelf at the heads of vertical poppets. The portion of the tie-plate which extends beyond the shelf plate must be supported by the wedges to prevent it from bending downwards when loaded. It is advisable to have this extension as short as possible, and this may render it difficult to obtain sufficient rivet area. In a recent case this was got over by fitting some of the supporting angles below the tie-plate and some above, thus putting the rivets into double sheer as shown in Fig. 21.

It is seldom or never necessary to slope the poppets to so great an angle as would make them stand normally to the hull surface, though some slope is inevitable in the case of vessels which are very fine forward if great length of poppet or a wide shelf is to be avoided. The usual condition is therefore that of a strut inclined both to hull and to ways and requiring shelf plates both at head and at heel. In the simplest case—that of an all-straight swing plate—the triangle of forces will be as shown in Fig. 22, J representing the transverse compressive force upon the hull.

Other cases in which swing plates and diagonal poppets are combined may be treated similarly, in the manner already explained when dealing with vertical poppets.

A more complicated case is that in which the whole swing plate is curved except in way of poppets and keel, and in which the lower tie-plate has to be sloped downwards to pass under the keel (Fig. 23). In this case the shaded block, consisting of sliding-way and wedging, divides the upward force P into a pressure S normal to the tie-plate and a frictional force F along its under surface. These three forces hold the block in equilibrium. The pressure S in turn is split up into a thrust Q along the poppets and a thrust G upon the shelf plate. The tension H is the sum of the frictional force F and the thrust G, all as shown on the diagram of forces. The vessel is supported on each side by four forces—the vertical component X of the pressure R between the poppets and the hull, the sum W of the vertical components of all the pressures R supplied by the curved portions of the swing plate, the vertical thrust V coming from the swing plate at the middle line, and another vertical thrust Z supplied by the tie-plate where it passes under the keel. The total transverse compression on the hull is C, equal to the sum of the tensions in the horizontal portions of the tie-plates where they cross the middle line.

This type of cradle has now been used for at least twelve large vessels, and in no case has there been any difficulty or damage.

For smaller vessels where the loads on the fore poppets are not too great, the swing and tie-plates may be replaced by chains or wire ropes wrapped round the poppets and tightened by screws or wedging.

Necessity for Diagonal Ties on Fore Poppet Structure.—After the stern has risen and the bow of the ship is resting upon the fore poppet structure, the latter is being dragged down the ways by its connection to, or friction against, the hull. This force is applied to the upper part of the structure. At the same time the friction between the ways tends to retard the lower ends of the poppets, and these two forces together tend to trip the poppets as indicated in Fig. 24. Published photographs show that in some cases such tripping has actually occurred.

To resist this tendency it is important that the whole forward cradle should be diagonally braced by a system of struts and ties as shown in Fig. 25, where struts S S are fitted in the form of ribands of stout timber and ties T T of steel plates, both sets being strongly bolted to the poppets.

(To be continued.)

THE EMPLOYMENT OF DISABLED SOLDIERS.—The Ministry of Labour, in conjunction with the War Pensions, &c., Statutory Committee, is setting up Trade Advisory Committees, consisting of equal numbers of employers' and workpeople's representatives, in the principal trades of the country, to advise upon certain of the questions concerning the training and employment of disabled men within these trades. In addition to securing the assistance of employers and workpeople in these trades, the establishment of these committees is intended to ensure that schemes for training disabled men for employment in these trades shall be fully considered by the interests concerned. Two of these Trade Advisory Committees, viz., those for electricity substation attendants and the willow cane and basket-making trade, have held their first meetings at the offices of the Employment Department of the Ministry of Labour. Important resolutions dealing with the training of disabled men were unanimously passed at these meetings and have been sent forward to the War Pensions, &c., Statutory Committee.

ELECTRICITY IN SWEDEN.—The Royal Waterfalls Board has entered upon an agreement with the Oxelösund Iron Works Company whereby all the blast-furnace gas from the works will be employed in the generation of electric energy. The aim is to produce a considerable quantity of electric current, of which the Waterfalls Board has secured the greater share; this will relieve the Västeras steam central reserve of the Alfkarleby power station and thereby reduce the expenditure for coal. The large Hemsjö Power Company has entered upon an agreement for supplying large portions of the Kronoberg district with electric current from its large power stations at Mörrumström, by means of a line via Ryd and Grimslöf to Huseby. At the latter place it is proposed to erect electric furnaces for the exploitation of iron ore found in the district. Negotiations are also proceeding between the Hemsjö Power Company and the State Railways with reference to supplying power to the latter's peat factory, now in course of erection at Vislanda. In connection with the regulation of Lake Salen with a view to obtain additional power, there is a scheme for laying dry some 1,000 hectares (2,470 acres) of land by means of electric pumping, the first attempt of this nature in Sweden. It is also proposed to extend the electric distribution scheme to Gransholm, Gemla and Växjö.

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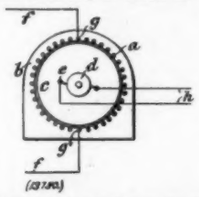
Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

ELECTRICAL APPARATUS.

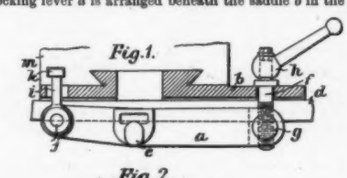
13,750/15. W. M. Mordey, London. Relays (2 *Figs.*) September 27, 1915.—This invention has reference to relays of the dynamo type usually comprising a field magnet energised by the received currents and an armature of direct-current kind driven by some external source of power to produce the augmented or relayed currents. A dynamo relay is, according to the present invention, so constructed electrically and magnetically that the iron therein is of such mass as to be worked at a very low magnetic induction, so low it may be, as to be within, or very near the non-hysteresis range of the material, and that the conductors thereof are of very large cross-section for the currents they have to carry, and of very low resistance, so that, of the very small amount of electric energy received, the proportion wasted in the apparatus is very small. A dynamo-relay constructed to meet the above conditions may have the field or exciting winding arranged wholly or partly as a distributed or face winding surrounding or partly surrounding the armature, as shown in the drawings,

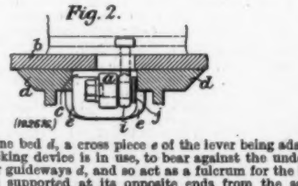


where *a* is a distributed or face winding on the field magnet *b*, and *c* is the commutator with armature *d* and brushes *e*. The received currents from the line *f* are caused to traverse the winding *a*. The received currents pass through the winding *a* between points *g* and *g*1, arranged at right angles, or approximately so, to the armature brushes *e*. The armature *c*, which is connected through its commutator *d* and the brushes *e* with the relayed circuit *h*, is driven at a high and approximately constant speed in any convenient way, for example, by an electric motor. Under these conditions the armature takes mechanical energy from the electric motor and, under the induction of the varying magnetic field produced by the received current as described, generates varying currents which in their variations reproduce those received from the line. These generated currents traverse the relayed circuit, the amount of energy so supplied to such circuit being greater than the received energy in any proportion of which the arrangement may be capable. (*Accepted January* 10, 1917.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

102,676. J. Higginson and H. Arundel, Stockport. Lathes. (4 *Figs.*) April 25, 1916.—This invention has for its object to provide a locking device for the saddles and cross slides of machine tools. The invention comprises the provision of a lever-like member supported at both ends from the saddle and having a portion between its points of support adapted to bear against a stationary part of the machine, so that when one of the supporting means is operated to draw its end of the lever towards the saddle, the lever fulcrums about the stationary part of the machine and draws the other supporting means firmly against the saddle, whereby the saddle is simultaneously locked at two points. In the application of the invention to a thread-milling machine, in which the saddle carries the cutter headstock, which is traversed across the machine by suitable means, the cutter being rotated upon the headstock in a known manner, the locking lever *a* is arranged beneath the saddle *b* in the gap *c*





in the machine bed *d*, a cross piece *e* of the lever being adapted, when the locking device is in use, to bear against the underside of the bed or guideways *d*, and so act as a fulcrum for the lever. The lever is supported at its opposite ends from the saddle, the support at one end consisting of a threaded stud *f* secured in a cross pin *g* in the bifurcated end of the lever and passing freely through a hole in the saddle, its outer end receiving a nut *h* having a handle thereon for ease of manipulation. The other support consists of an eyebolt *i* secured upon a pin *j* through the lever and passing through a hole in the saddle, the enlarged head *k* of the bolt engaging a T-slot in the headstock *m*. With the arrangement aforesaid, when the nut *h* is tightened up, the lever *a* fulcrums about the part *e* which engages the underside of the machine bed, and so draws down the eyebolt *i*. The saddle *b* is therefore locked at its opposite sides and the headstock *m* at one side. Twisting of the saddle is thus effectually prevented. (*Sealed.*)

MOTOR ROAD VEHICLES.

102,700. F. H. Royce, B. I. Day, and Rolls-Royce, Limited, Derby. Friction Clutches. (1 *Fig.*) July 28, 1916.—This invention has reference to spring-operated friction clutches for motor vehicles. *a* is the crankshaft of the engine. *b* is the driving member of the clutch, with serrations on the internal circumference in engagement with serrations on the ring a^3. *c* is the driven member of the clutch. b^2 are friction discs alternatively serrated on the inner and outer circumference, and such serrations being respectively in engagement with corresponding serrations on the members *b* and *c* in the usual manner. b^5 is the anchored presser plate. b^6 is the movable presser

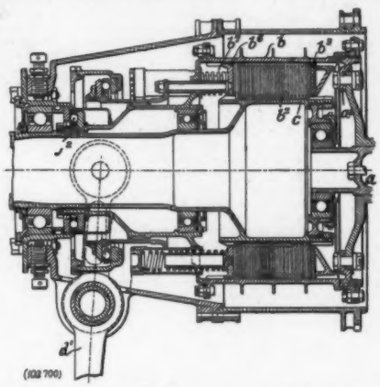
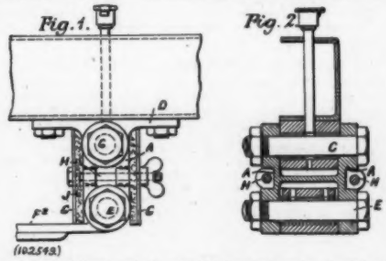


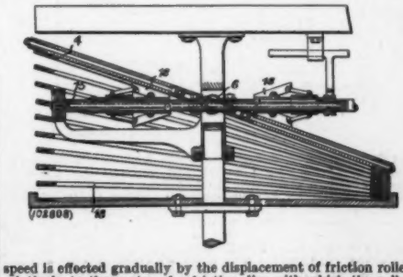
plate receiving and distributing pressure from the springs b^7. *d* is the trunnion actuated by the lever d^3. The effect of the above construction is that when the clutch is engaged all the pressure exerted by the springs is contained within the member *b*, and hence no axial pressure is exerted on either of the shafts, and when the clutch is disengaged the axial movement or pressure is entirely or almost entirely taken at the ball journal f^2, one race of which is supported by the case or frame, while any slight axial movement of the member *b* is accommodated by the serrations on the coupling members *b* and a^3, and no axial movement or pressure is communicated to the crankshaft *a*. (*Sealed.*)

102,549. R. W. Maudsley, and the Standard Motor Company, Limited, Coventry. Springs. (2 *Figs.*) March 4, 1916.—According to this invention, there is fitted in front and behind each shackle a plate, and the two plates are fitted to the edges of the shackles, so that they, with the links, form a chamber which can be rendered oil-tight by interposing any suitable packing, such as felt, where required. The plates may be bolted together so as to grip the shackles, or they may be joined to the shackles in a more or less permanent fashion, the result in any case being to form a rectangular chamber, which is closed at the top and bottom by the spring-eye and part of the spring hanger respectively. To this chamber is supplied oil, which may be done in various ways. The shackle may be of H-section, comprising a pair of flat links A connected together by a web. These



are suspended from a pin C, which is free to turn in a bush in the spring hanger D fixed to the frame. The other ends of the links carry another pin E, which works in a bush in the eye of the spring F2. The hanger D is formed as usual with a boss which is bored out for the pin C, and the width across this boss, and also the width of the spring-eye, is equal to the width of the links A, as will be clear from Fig 1. Thus when the plates G are applied to the edges of the links they make an oil-tight joint along the edges of the boss and spring-eye (see Fig. 1). The plates G may be drawn together by bolts H, and between the plates and links are arranged felt pads J. Thus the plates G and the links A form the walls of the chamber, which is closed at the top and bottom by the boss on the spring hanger and the spring-eye. Lubricant may be supplied to this chamber in any suitable manner. (*Sealed.*)

102808. J. A. Hill, Sheffield. Change-Speed Gear. (4 *Figs.*) October 28, 1916. This invention relates to an improved change-speed gear of the friction type in which the change of the



speed is effected gradually by the displacement of friction rollers relatively to the centre of a friction disc with which the rollers come into contact. The change-speed gear constructed according to the present invention consists of a friction disc 4 capable of oscillating on an axis 6 perpendicular to a shaft 15 carrying conical rollers 18 arranged in frictional contact with the opposite faces of the friction disc, the inclination of the conical surfaces of the rollers in their longitudinal direction being made variable and the variation of this inclination being effected automatically and simultaneously with the sliding movement of the conical rollers on the shaft, the friction disc being forced, by means of an elastic device 11 connected thereto and to the driving or driven shaft, against the conical surfaces of the rollers. In the gear according to the present invention the apex of the conical surface of each conical roller always remains in one and the same position on the axis of rotation of the rollers when the latter are shifted relatively to the axis of the friction disc and the inclinations of the conical surfaces thereof are simultaneously varied, the result being that the surfaces of the conical rollers and the friction disc in contact with each other must necessarily remain parallel to each other at all speeds. (*Accepted December* 30, 1916.)

RAILWAYS AND TRAMWAYS.

102,742. A. Spencer, London. Bogies. (6 *Figs.*) January 3, 1916.—In the construction of a bogie, according to this invention, the springs of the suspended rods or links are located at the inner sides of the longitudinal side members of the bogie frame, and the plates or washers on which they rest are mounted to rock on fixed plates or supports through which the rod or links extend. The bolster, adapted to directly support a vehicle through a central swivel plate *b* and side bearing blocks, is supported through springs *d* upon a spring plank *e* that is carried by rods or links *f* through bars *g*. Each bar *g*, for a portion midway of its length, is formed with a rocking edge at the top, on which is mounted a bracket *h*. The brackets *h* are secured

Fig. 1.

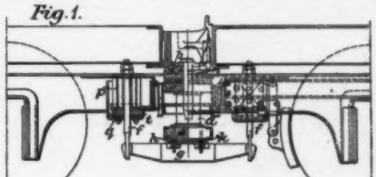
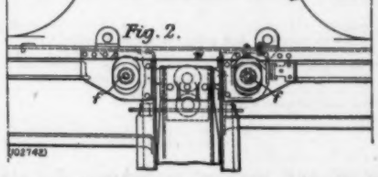
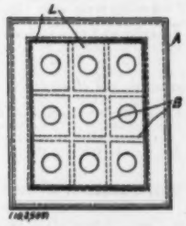


Fig. 2.



by bolts to the spring plank *e*, wooden adjusting blocks being interposed between the plank and the brackets. The ends of the bars *g* are hook-shaped and engage slots formed therefor in the lower ends of the rods or links *f*. The upper end of the rods or links are screw-threaded and fitted with nuts bearing on washers or plates that rest on springs *p*. The springs are carried on plates or washers *q*, each having at its under side a suitably shaped projection or rib adapted to rock transversely of the bogie on a plate that is bolted to a bracket *t* fixed to the adjacent side bar and cross-bearer of the bogie frame *w*. In the example illustrated the rib is so formed as to prevent longitudinal rocking or other movement. (*Accepted December* 30, 1916.)

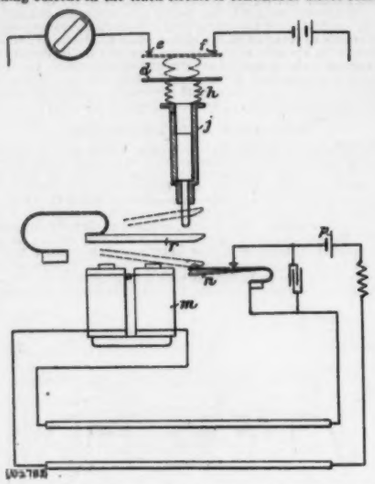
102,509. H. W. Firth, Hutton, and F. W. Leake, Leytonstone. Railway Signalling. (3 *Figs.*) January 1, 1916.—The invention relates to means for indicating to the driver of a train at terminal stations, or other places where routes diverge, the route that has been set for that train. According to the present invention, in which no semaphore arm is provided, the route set is indicated by combinations of electric lamps, lighted or illuminated discs or the like, each combination of groups shown corresponding to a given route. The lamps, or other devices, are disposed in groups, so arranged that a given group or plurality of groups is actuated by the operation of a single route lever. All the devices forming part of one and the same group are actuated together by the same operating mechanism.



A is a metal frame provided with partitions B for dividing off the spaces L occupied by the lamps. The borders of the frame surrounding the enclosed spaces containing the lamps are illuminated by lamps behind a ground glass screen. Any given route is indicated by the number and disposition of the lamps lighted, and in the example shown it is assumed that the signals corresponding to the routes 1–9 are arranged in a system similar to that adopted in ordinary playing cards for indicating the numerical value of any card. Route 1 is indicated by the central lamp, route 2 by the top and bottom lamps of the central vertical division, 3 by the three lamps of the central vertical division, 4 by the top and bottom lamps of the outside divisions and so on. (*Sealed.*)

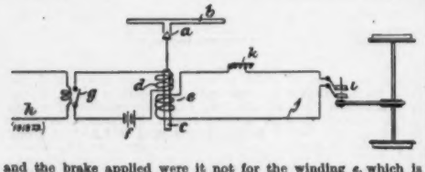
102,793. W. R. Sykes' Interlocking Signal Company, Limited, and R. W. Tarrant, London. Signalling. (1 *Fig.*) June 27, 1916.—This invention relates to improved electric relay apparatus for use in connection with a railway track-circuit, and it comprises a relay winding *m*, a source of continuous direct current *p* and a spring-closed switch *n* (hereinafter referred to as the relay switch), all connected in series with one another in the track-circuit; a pump *j*, whereof the working cylinder is connected with a fluid pressure-accumulator *h* having a movable part *d* adapted, when the accumulator is inflated beyond a certain extent, to close a switch *e*, *f* (hereinafter referred to as the controlled switch) interposed in the external circuit controlled by the relay; and a spring-supported armature *r* for the relay winding so mounted as to occupy, when at rest, such a position relatively to both the relay switch and the movable element of the pump as to be adapted, when caused to oscillate beyond certain limits

to alternately open the said switch and actuate the said movable element; the arrangement being such that so long only as normal working current conditions prevail in the track-circuit will the relay armature be alternately attracted so as to open the relay switch and thereafter allowed, on the breaking of the track-circuit, to rebound so as to actuate the movable element of the pump (thus bringing about the charging of the pressure-accumulator) and at the same time permit the reclosing of the relay switch and the consequent repetition of the cycle of operations. The normal working current in the track-circuit is continuous direct-current



of predetermined polarity and potential, and the strength of the spring which supports the relay armature is made such as to cause the armature, when the track-circuit is broken, to rebound from its attracted position with the force required for actuating the movable element of the pump, whilst provision is made for leakage from the pressure-capacity (comprised within the pump cylinder and pressure-accumulator) at a rate such that only so long as the oscillations of the armature have a predetermined frequency or amplitude, or both, will the pressure accumulator be charged sufficiently to hold the controlled switch closed. (*Accepted December* 30, 1916.)

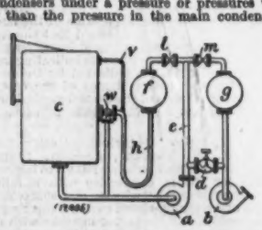
101,873. C. H. Woodward, Bournemouth. Brake Control. (1 *Fig.*) October 21, 1915.—According to this invention, an air-brake valve is operated by a direct electric current and also by an alternating current, the direct current operating to apply the brake under the danger conditions, while the alternating current prevents this application so long as the speed of the train does not exceed a predetermined limit. The brake valve *a* of the air train pipe *b* is operated by a plunger *c* provided with two windings *d* and *e*. The winding *d* is energised from a battery *f*, and tends to keep the valve *a* closed as long as its circuit is closed. Under danger conditions, the circuit is opened at *g* by the change in the train-control circuit *h*, and the valve *a* would be opened



and the brake applied were it not for the winding *e*, which is supplied with alternating current from a small constant-voltage generator *i*, driven from the train axle. The frequency of the alternations impressed upon the circuit *j* consequently depends upon the speed of the train, and by a suitable adjustment of the impedance of the circuit, for example, by means of the adjustable inductance *k*, the current in the winding *e* will, when the speed exceeds a given limit, be insufficient to hold up the valve *a*, which is then under the control of the direct-current circuit. If the condition alters to danger, the winding *d* is de-energised, the valve *a* opens and applies the brakes until the decreasing speed of the train reduces the frequency of the alternating current and allows the winding *e* to again close the valve *a*, which will remain closed as long as the speed is below the predetermined limit. (*Sealed.*)

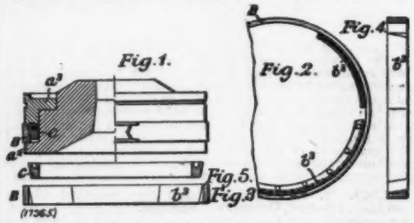
STEAM-ENGINES, BOILERS, EVAPORATORS, &c.

17,405/15. D. B. Morison, Hartlepool. Steam Condensing Plant. (3 *Figs.*) December 13, 1915.—This invention relates to apparatus for withdrawing condensate, with or without condensing water, from a main condenser under vacuum and delivering a part or the whole of the water to one or more auxiliary condensers under a pressure or pressures which is, or are, greater than the pressure in the main condenser and less



than atmospheric, and through which auxiliary condenser or condensers the air withdrawn from the main condenser is discharged on its way to the atmosphere. According to this invention, a pump withdraws condensate, with or without condensing water, from the main condenser, and another pump, together, it may be, with the first-mentioned pump, discharges the water to the atmosphere either direct or otherwise, a suitable water resistance or water head producing device being provided on the discharge side of the pump or first stage which withdraws water from the main condenser. From such device and/or the pipe or passage leading thereto, one or more pipes is or are led to one or more auxiliary condensers, the arrangement being such that the water resistance or water head producing device causes a preferential supply of water to be delivered to the auxiliary condenser or condensers. The condensate is withdrawn from the main condenser *c* by a two-stage pump *a*, *b*. The first stage *a* delivers through a loaded valve *d* to the second stage *b*, which discharges to the atmosphere, and a pipe *e* is led from the connection between the first stage *a* and the loaded valve *d* to two auxiliary condensers *f* and *g* working under different pressures, the resistance to the flow of water through the valve *d* being sufficient to cause a preferential supply of water to the auxiliary condensers. The water from the auxiliary condenser *f*, which is under the lower absolute pressure, is discharged through a looped pipe *h* and cock *w* into the main condenser *c* or into the suction of the first stage *a* of the pump, a vent pipe *v* being provided so that the air separated from the water may pass back into the main condenser. The condensate from the second auxiliary condenser *g*, which is under a higher absolute pressure, is discharged into the suction of the second stage *b*. Valves *l* and *m* are provided for controlling the quantity of water delivered to the auxiliary condensers, and with the object of preventing back-flow into the main condenser in the event of derangement, the valve *m* may be of the non-return type. (*Sealed.*)

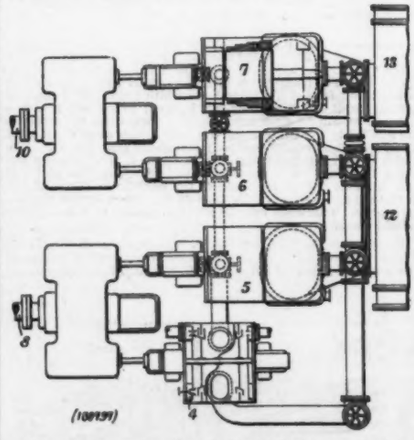
17,365/15. R. J. B. Barker, Liverpool, and R. Anderson, Greenock. Metallic Piston Packing. (8 *Figs.*) December 11, 1915.—This invention relates to packing for pistons, comprising a split piston ring of conical configuration on the inside and a wedge ring coned externally to fit said conical part and pressed by means of springs interposed between it and the junk ring. According to the present invention, the conical portion of the piston ring is lightened by arranging the internal conical portion in discontinuous segments, or, in the case of piston rings of small diameter suitable for valves, in grooving the conical portion with a series of circumferential grooves. B is the piston ring, the outer surface of which is cylindrical and the inner surface of which is coned. The conical part, in rings of substantial diameter, is cut away or omitted at three or more



places symmetrically arranged; for instance, in the example illustrated, three coned parts b^3 are shown, the section of the ring between these coned parts being rectangular; this is shown clearly in Figs. 3 and 4. The plane surfaces of the ring fit the inside faces of the junk ring a^3 and the flange a^2. C is the wedge ring; the outer surface is conical, the cone angle being equal to that of the parts b^3 of the piston ring; the ring C is shorter axially than the distance between the junk ring a^3 and the flange a^2. Helical springs fitting loosely in equally spaced recesses in the wedge ring are interposed between the wedge ring and the junk ring; the length of these springs is such that the necessary axial pressure is transmitted to the wedge ring, and as the piston ring wears the wedge ring follows up; the necessary spring pressure may be maintained by inserting making-up pieces in the recesses. (*Sealed.*)

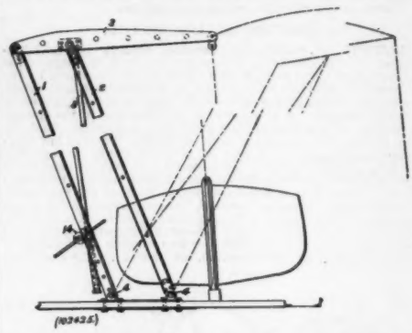
SHIPS AND NAUTICAL APPLIANCES.

100,797. The Westinghouse Machine Company, East Pittsburg, U.S.A. Marine Turbine Installations. (3 *Figs.*) June 30, 1915.—According to the invention, the improved turbine installation comprises a high-pressure section, a plurality of low-pressure sections operating in parallel on fluid delivered from the high-pressure section, and two condensers receiving fluid delivered from the low-pressure section, each condenser serving less than the entire number of low-pressure sections, and one of the condensers being of materially greater capacity, preferably twice the capacity, of the other condenser. The apparatus illustrated includes a high-pressure turbine section 4



and three low-pressure sections 5, 6 and 7, which are adapted to operate in parallel on the motive fluid discharge from the high-pressure section, and which in effect form a multiple-flow low-pressure section for the high-pressure section 4. In addition to this, means are provided such that the fluid exhausted from the high-pressure section may be delivered to less than the total number of low-pressure sections, so that one or more of the low-pressure sections may be rendered inoperative under certain load and speed conditions. The rotor elements of the sections 6, 7, are shown operatively connected to a propeller shaft 10. The rotor element of the section 4 and the rotor element of the section 5 are connected to a second propeller shaft 8. A condenser 12 receives the fluid exhausted from the sections 5 and 6, and a condenser 13 of half the capacity of the condenser 12 receives the fluid exhausted from the section 7. (*Sealed.*)

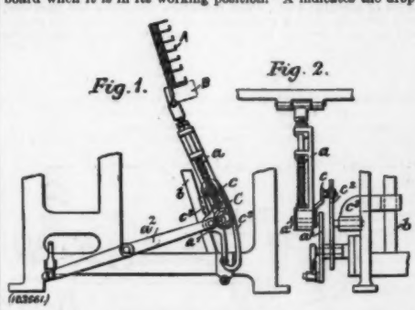
102,425. W. McClelland, Rock Ferry. Ships' Davits. (4 *Figs.*) March 24, 1916.—This invention has reference to ships' davits of the type comprising two legs spaced apart, pivoted at their lower ends and having on their upper ends a gantry member, to which the other members are connected at points apart by movable joints or connections. According to this invention, the gantry member 3 is carried on the upper ends of two pivoted parallel or nearly parallel legs, 1, 2, the pivots 4, about which they move, being at the lower ends; and the gantry member 3—which is, roughly, horizontal—is supported by joints from the supporting members or legs 1, 2 at their upper ends; whilst the operating mechanism 14, consisting of a screw gear, tooth gear, or the like, is carried on the leg 1, and operates upon a diagonal member 8 which, at its lower part, is carried in and by this gear, and at its upper end is connected to the leg 2 or to the gantry member near the connection of this leg with the



gantry member. Normally the supporting parallel members will be in an inclined position, the inclination being inboard, and in this position the outer end of the gantry member will lie over the boat; and from it the supporting and raising or lowering tackle will be suspended. The movement of the path of this outer end by the operating mechanism will be a slightly rising one for the first portion, so that the boat is first lifted somewhat from the chocks and moved outboard; afterwards the path may curve downwards or as desired. In the outboard position the parallel members will be in an inclined position outboard of their pivots, and the boat will be supported beyond the side of the ship, in which position it is ready for lowering, and can be lowered by the raising and lowering tackle from the gantry. Conversely, the latter position of the davits will be the one in which they will lie when it is desired to lift a boat from the sea and bring it aboard on to the ship. (*Accepted December* 13, 1916.)

TEXTILE MACHINERY.

102,661. Butterworth and Dickinson, Limited, and A. Prior, Burnley. Drop-Box Looms. (2 *Figs.*) March 27, 1916.—This invention relates to drop-box motions of looms and to that type of motion in which a part known as the box-rod is connected with, and receives its motion from, a lever known as the box-lever. According to this invention, instead of the box-lever being connected directly with the box-rod, it is connected therewith through the intervention of a lever or eccentric, to which a variable turning motion is imparted from any convenient going part of the loom to raise the boxes during their backward movement and lower them on their forward movement, with the result that relative movement between the boxes and guides is eliminated and each box remains true with the race-board when it is in its working position. A indicates the drop-



box, B the race-board, C the eccentric. The variable turning movement of the eccentric C is conveniently obtained by utilising the variation in the angular movement that takes place between the sley sword *b* and the box-rod *a*, as the latter is moved from one extreme position to the other. For this purpose the eccentric is shown mounted on the ordinary stud a^1, which projects from the box-lever a^2, and to which stud the box-rod *a* is usually connected. The eccentric is formed with an arm *c*, which advantageously carries a pin or bowl for engagement with a slotted cam-plate c^2, which is capable of angular adjustment in a bracket c^3, which may be bolted or otherwise secured to the sley sword *b*. Encircling the eccentric is a strap formed or provided on the end of the box-rod *a*. (*Accepted December* 29, 1916.)

PROHIBITION OF INSPECTION OF CERTAIN PATENTS IN ITALY.—H.M. Embassy at Rome reports, says *The Board of Trade Journal*, that a Royal Decree, dated January 18, prohibits, for the duration of the war, the inspection or copying of descriptions or designs of inventions concerning warlike material, or the defence of the State, which have been patented since December 31, 1915, unless an applicant can show that he has received the express authorisation of the Minister of War or Marine.